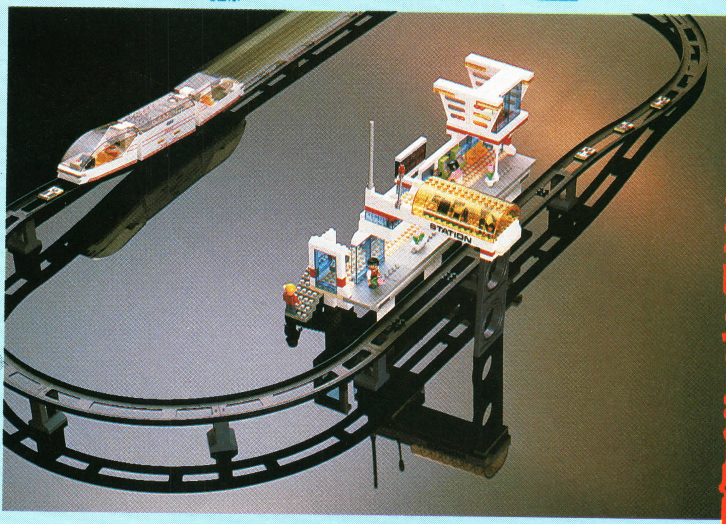
HI-TECH TOYS

Ripmax plc

Ripmax plc

***Radio-controlled** models are bought unassembled in kit form, and can be customized with accessories, such as the oversize shock absorbers on this car. Racing models can attain speeds of 45 km/h, while off-road and buggy cars are built for rough terrain.*

***Bar codes** on the track of this CompuTrain monorail are picked up by a light sensor as the train passes over them. The bar codes give the train a variety of instructions and can be moved about the track.*



Maison Joseph Battat Ltd, Montreal

THE TECHNOLOGICAL advances that are changing our world are also finding their way into the latest toys. As a result, everything from model train-sets to ray-guns is becoming increasingly sophisticated.

Some new toys make use of microprocessors, or 'computers-on-a-chip'. These allow a variety of instructions to be stored and carried out automatically. In many cases, the built-in microprocessor can be programmed so that the toy behaves in a different way each time it is played with.

Omnibot 2000 is a programmable, remote-control robot (see Robotics, New Technology, p143). It moves over the floor on wheels and picks up objects with two mobile arms. Its memory can store instructions up to seven days in advance, and a tape recorder acts as the robot's voice box for passing on pre-recorded messages.

CompuTrain

Even train-sets have been given a 21st-century look through the use of microprocessors. CompuTrain, for instance, is a futuristic monorail, the movement of which is controlled by 'bar codes' similar to those on many supermarket products. Small plastic blocks marked with various bar codes can be placed anywhere around the track. Then, as the train passes over each bar a sensor scans the pattern of bar-lines with a light beam. The sensor feeds this information to an on-board microprocessor which, in turn, is connected to a battery-driven motor, lights and a small loudspeaker. According to the message on the code, the train may stop for a few seconds before moving on, decrease speed, reverse direction, or shut down after a certain number of passes over the bar.

Model planes, boats and cars that can be controlled remotely have been available for a number of years. But advances in microprocessors and electronics have opened up new possibilities for the enthusiast.

Transmitting commands

Model aircraft, for example, are powered by a miniature petrol-driven engine connected by a shaft

Tony Stone Photo Library

1960s and 1970s. Linked to mechanical arms with motorized joints, the computers could be programmed to instruct the arm to move in a variety of ways. With different tools added, the robot arm can carry out a wide range of jobs, such as cutting, welding, polishing, painting and assembling parts.

In complicated operations, the computer calculates the angles through which each of the joints turns. Sensors feed the joint angles

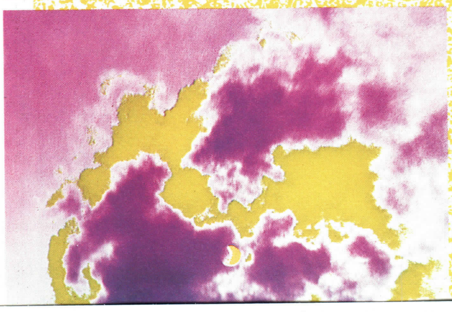
with lasers are powerful enough to cut through sheet steel but also precise enough to cut the shell of an egg without damaging the delicate contents.

Robot welders

The most common use of robots today is in the motor industry. Robots are used to spot weld panels and frames to complete the assembly of a car. A robot can also be used to

lear engineers tighten and loosen the massive bolts holding down the lid of a nuclear reactor. These huge bolts can weigh up to 450 kg each and must be adjusted every time the nuclear fuel is replaced. While the process of unbolting and replacing the studs with manual tools took 32 hours and required the presence of eight operators, the single-operator controlled robot can complete the same job in 12 hours.

ELECTRICITY FROM NUCLEAR POWER



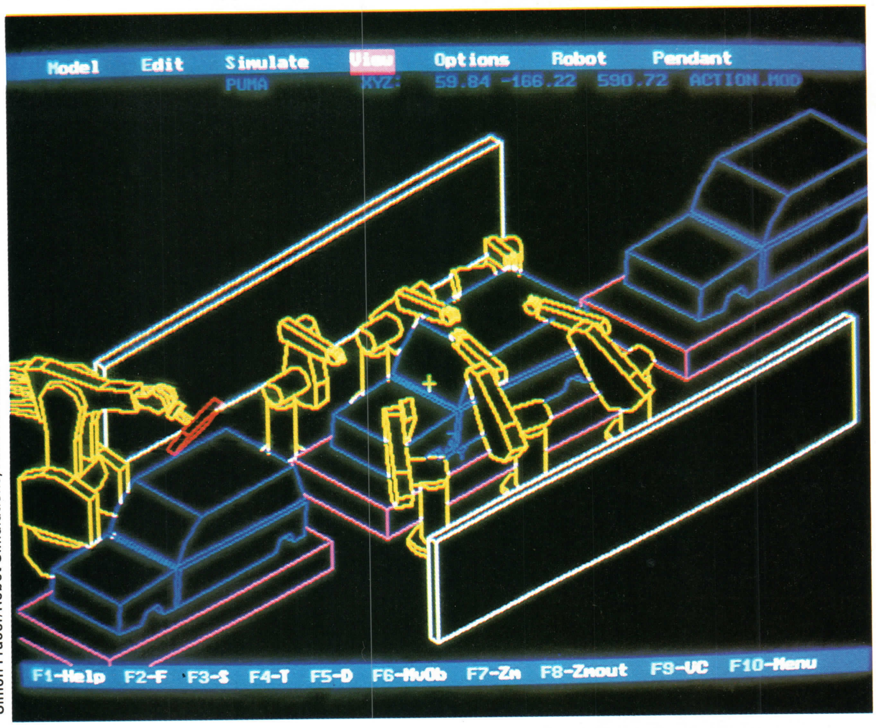
Electricity is generated continuously in stations powered by coal, oil – or by nuclear fuel. In such power stations heat converts water to steam that drives a turbo-generator to produce electricity. In a nuclear-powered plant, the heat is produced by splitting atoms of uranium inside a nuclear reactor.

Rods of uranium inside metal cans, or pins of 'enriched' uranium that has been specially processed, are lowered into the core of a reactor. The uranium

degrees. The mix enters at one end and travels slowly down the kiln towards the heat source, at about 30 metres per hour, passing out at the other end cooked into lumps of cement clinker, which is later crushed into a powder. The kiln is in continuous operation at temperatures of up to 1400°C, only shutting down for occasional repair.

Semi-wet process

To save energy, the wet process has been modified: the slurry is fed

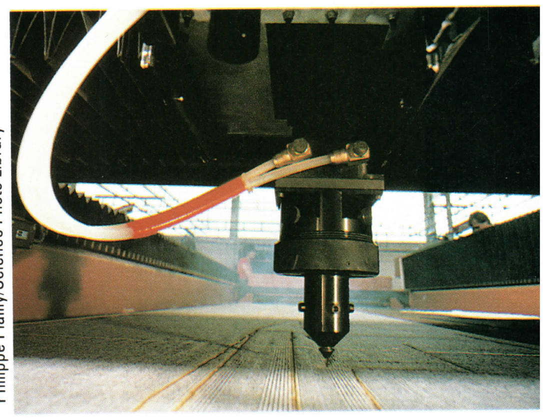


Simon Fraser/Robot Simulations, Newcastle/SPL

Computer graphics are used to plan a fully automated production line, avoiding the need for wasteful trial and error when the line is built.

The other major type of robot, the Automatic Guided Vehicle (AGV), is used to carry goods and components around in factories and warehouses. This robot truck follows underground cables or painted

Laser 'scissors' can cut large amounts of fabric for clothes' manufacturers quickly, tirelessly and with great accuracy.



Philippe Plailly/Science Photo Library

A robot-based workstation includes a robot arm, its control system, tools and accessories, a conveyer system for the workpieces and the instruction software.

A British-made robot was used to weld together hundreds of tubes to produce an exhaust nozzle for the Ariane–5 space rocket. This was the first time that a robot with a direct drive — that is, no gears between the motor and the welding arm — was used for welding. Such direct-drive robots are smoother and more accurate than conventionally geared robots.

The robot carried a sensor that contained a laser and a camera eye. Together, these scanned the path ahead of the welder up to twenty times a second and fed the information back to a computer, so ensuring the best position for the robot to carry out an accurate welding seam.

DRIVERLESS TRAINS

Automation has replaced train drivers in some rail systems, such as the Bay Area Rapid Transit System (BART) in the San Francisco-Oakland area of California, USA. A similar system is in use in the docklands light railway in London, Great Britain. On the BART railway the trains are kept at the same distance from each other and their speeds are automatically regulated to keep them within safety limits. It is operated by two identical computers, one backing up the other. Manual controls exist if both computers fail.

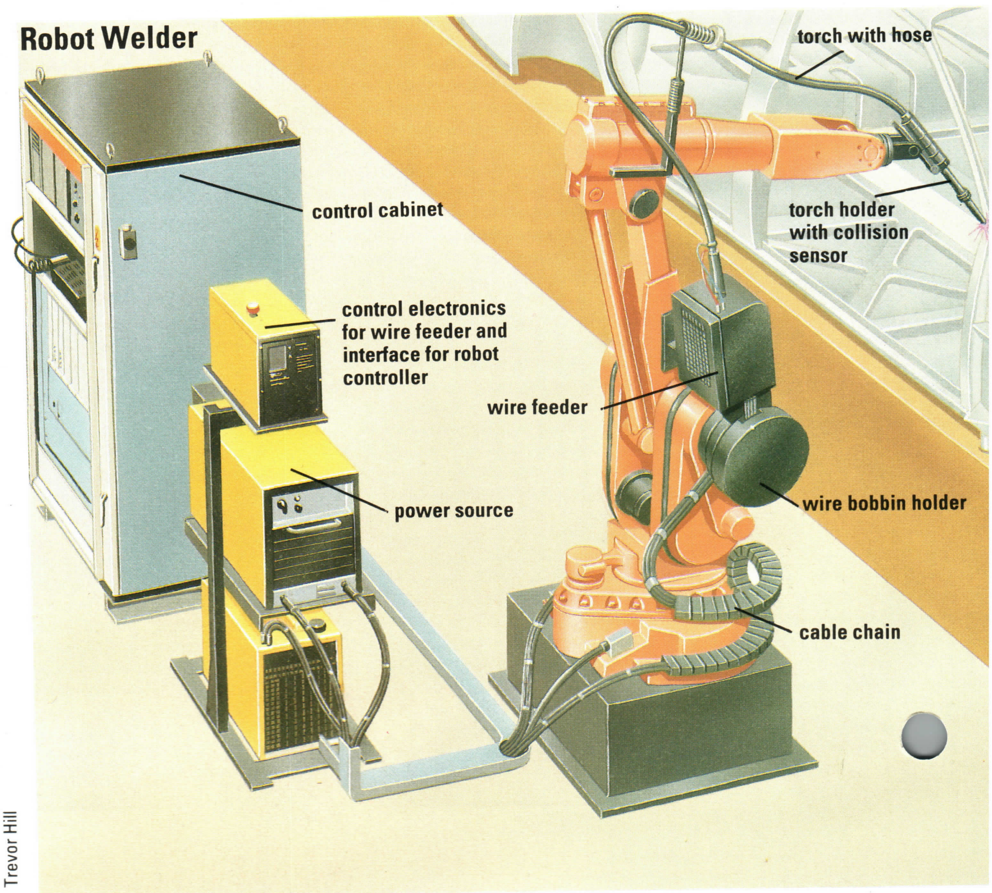
Joy-stick

Achieving a high-grade finish on a stainless-steel sink is time-consuming and can cause fatigue among workers. But it is a simple task for a robot with the right tools and a suitable program. The vital programming can be done by operators using a joy-stick to control the robot's movements, while it 'learns' the memory sequence of movements. Similarly, coating acrylic baths with glass-reinforcing polyester used to be a slow and hazardous process, but now a robot can spray on the three main ingredients in the required proportions.

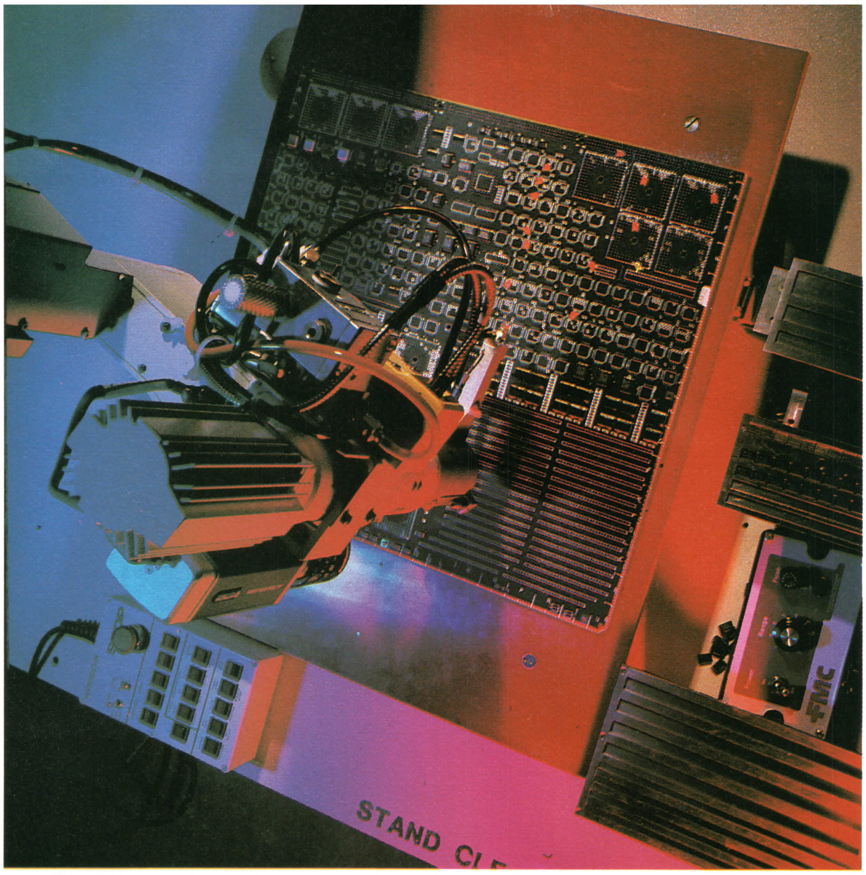
AGV

There is even a prototype robot sheepshearer. This holds the animal while robot clippers, guided by sensors, follow the line of the body.

Robot Welder



Trevor Hill



Tony Stone Photo Library, London

***Robot reproduction** is a fact of life – here the circuit boards that form the brain of future robots are automatically tested.*

white lines. AGVs have revolutionized the tedious and time-consuming work in warehouses and stores. Some libraries now have robots that can find a selected book or videotape on the shelf and deliver it to the customer.

Japanese companies are turning to robots to solve problems in the country's booming construction industry. For example, robots are used to move and arrange the long, heavy steel bars needed for the foundations of nuclear power plants.

Lectra Systems Ltd

***Designing shoes** on a computer screen is fast, efficient and allows a new model to be instantly evaluated. Once satisfied with a design, the computer can drive automatic cutters and assembly machines to produce a prototype.*

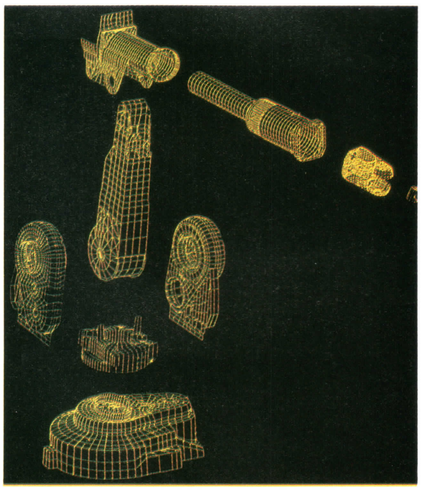


ABB Robotics

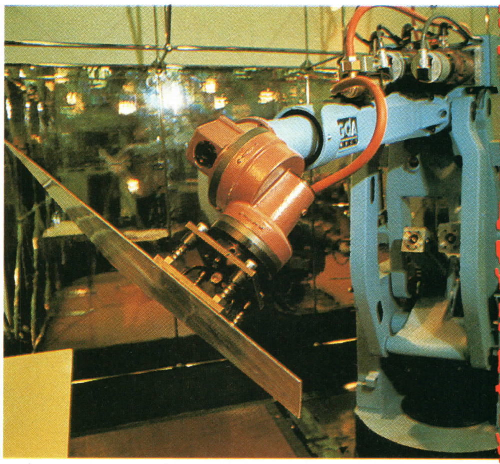
Similarly, when a dam is being built, one robot carries concrete to where it is needed, another robot assembles frames on to which the concrete is poured, then a final robot compresses the concrete. It is claimed that the robots reduce the number of manual workers needed to do the job by more than two-thirds.

Before engineers introduce an automated robot system, they create three-dimensional simulated images of different types of robot on a computer. This enables them to compare the performances and choose the best one.

***Computer-aided design** is used in the development of industrial robots and the tools and accessories employed in production systems.*

Voice control

In the future, robots will receive instructions by voice. They will also be more intelligent with super computers that will enable them to interpret and carry out commands without following a rigid programme. For example, such a robot will be able to 'see' an object in its path with sensors and react accordingly. It will also be able to determine when objects on an assembly line have moved, or when to adjust a process (such as welding) automatically.



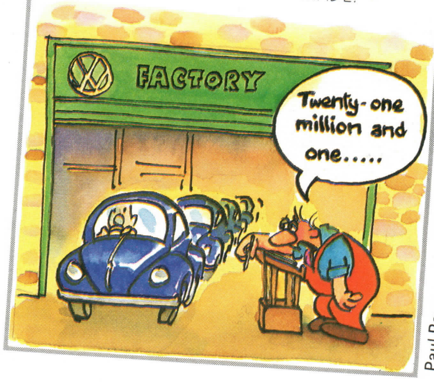
Gontier/Jerrican/SPL

***Handling goods** such as sheets of glass is a task that can be left to programmed robot carriers, freeing humans for important creative or management jobs.*

Just amazing!

BEETLEMANIA

OVER 21 MILLION VW BEETLES HAVE BEEN BUILT SINCE 1938, MAKING IT THE LONGEST PRODUCTION RUN OF ANY CAR – AND THEY'RE STILL BEING MADE!



Paul Raymonde

Tony Stone Photo Library, London

All kinds of calculations can be incorporated into the computer before a prototype is produced. This enables engineers to design products that actually take into account the automatic tools and workstations that will be used to manufacture them. The result is that modified or new products can be rapidly manufactured in response to changes in market taste.

Rapid response

Finally, all the details of sales and stock levels can be kept on computers, so that projections can be made about which products sell best. In this way, production can automatically be stepped up to meet extra demand on high-selling items or slowed if demand falls.

The fine control of parts or materials into a factory and products out, in response to customer demand, brings both increased efficiency and substantial cost savings.

Automation does not only involve robots. It has also found its way into many companies in the form of computer-aided design and supervise manufacturing (CAD/CAM). This involves using computers to design, manufacture and keep records on products as diverse as shoes or trucks. In CAD the designer works with a three-dimensional graphic model or blueprint on the computer screen. By manipulating the design, he can change things quickly rather than having to keep coming up with new designs on the traditional draughtsman's boards. Modifications to the basic design can be made with ease, and production lines changes rapidly.

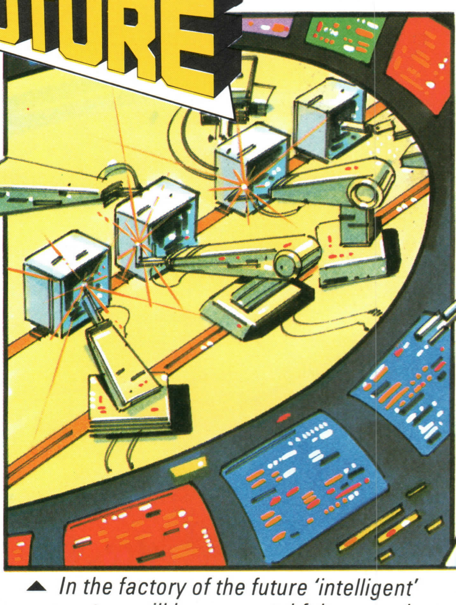
The control room *of an automated aluminium mill, overlooking the main production areas. The human operatives mind the machines and do the maintenance work that the automatic monitoring systems indicate is necessary.*

Modern printing *is highly automated. This press in Singapore is fully computerized with the printers freed to keep a check on quality.*

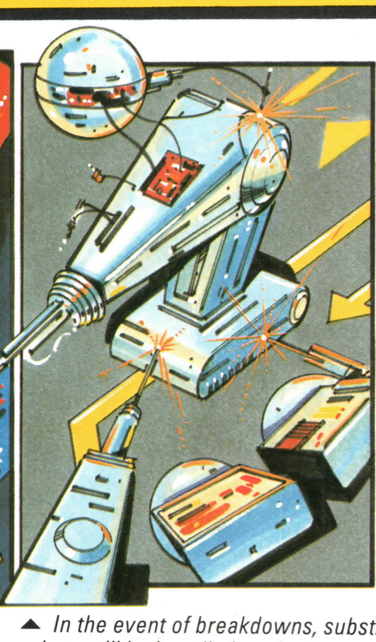
R Ian Lloyd/Hutchison Library

INTO THE FUTURE

THE AUTOMATED FACTORY



▲ *In the factory of the future 'intelligent' computers will keep a watchful eye on the working robots, freeing humans for all-important planning.*



▲ *In the event of breakdowns, substitute robots will be installed on the line and the faulty robot sent to the automatic 'troubleshooting' repair station.*

▲ *In the event of an emergency such as a fire, robot fire-fighters, having automatically sensed the source, will move in and tackle the problem.*

Joe Lawrence

Pascal Rondeau/Allsport

Pascal Rondeau/Allsport

- IN THE AIR
- UNDERWATER
- FROM SPACE

ESCAPE!

***Formula 1** racing cars are designed with safety in mind. Immensely strong carbon fibre/Kevlar one-piece chassis, roll-over bars, a six-point harness, automatic fire extinguishers and built-in oxygen supply combine to help the driver survive (inset) even the worst crashes.*

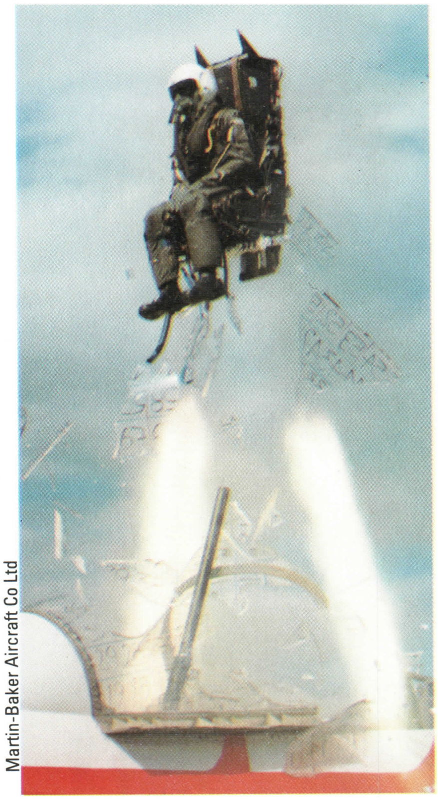
HIGH-SPEED CIVIL AND military transportation is fine – until, that is, something goes wrong. Then, efficient and effective methods of escape become essential.

One of the most dramatic methods of escape is the ejection seat provided for pilots and co-pilots of military jets. Once activated, it shoots its occupant out of the cockpit in less than half a second. A small rocket motor underneath then fires to blast the seat several hundred metres clear of the aircraft, then an automatic parachute system is deployed.

Once safely down, however, the crewman's problems may not be over. If he bailed out over the sea or a remote region of land, any rescue could still be many hours away. To help him stay alive until then, the seat pan of the ejection seat contains an inflatable dinghy together with a variety of survival aids.

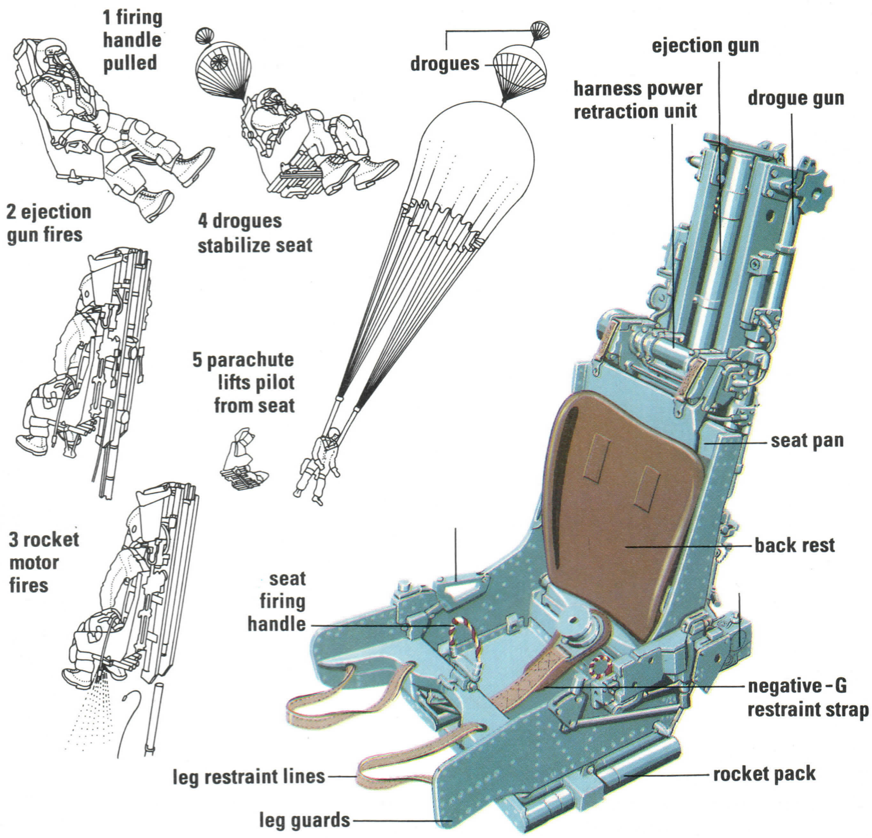
Pressurized cabin

Passengers of a stricken airliner have no way to escape while in flight. Since the cabin is pressurized, even the smallest opening between the cabin and the outside could prove disastrous. The violent



Martin-Baker Aircraft Co Ltd

***Martin-Baker** ejector seats have saved well over 5,000 lives. The Mark 10 version, being tested on a rocket-powered sled (above), is fully automatic.*



Martin-Baker Aircraft Co Ltd/Trevor Hill

rush of escaping air would suck absolutely any objects nearby that were loose – including passengers – out through the gap. Thus, it would be impossible, for instance, to open a door to let people attempt a parachute jump.

Oxygen masks

In the event of a drop in cabin pressure, oxygen masks are released from the bottom of the luggage rack over the passenger seats. These allow passengers to continue breathing normally until the aircraft can make an emergency landing.

Once on the ground, it is vital that any survivors get clear of the plane as soon as possible since leaking fuel can quickly ignite and turn into a deadly fireball. Also, if a fire breaks out inside it will fill the passenger cabin with choking smoke and intense heat. Emergency procedures must provide for the complete evacuation of the aircraft within 90 seconds.

As well as the regular doors, airliners are equipped with emergency exits over the wings and at the back. These, however, are high off the ground – 5.8 metres in the case of a Boeing 747.

Inflatable chutes

To enable a fast but safe evacuation, canvas chutes are automatically unfurled and inflated from the base of the doors in an emergency. Passengers then jump out and slide down the chutes to safety.

In case an airliner has to ditch in the sea, life-jackets are stowed under each seat. These simply fit over the head and tie around the waist. Some self-inflate when a toggle is pulled, others have to be blown up by the wearer. A water-activated flashing light fitted to the vest is intended to help rescue teams locate anyone floating near the wreckage. In addition, each passenger seat can itself be used as a flotation device and the airliner carries several giant inflatable life-rafts equipped with survival aids.

SHUTTLE EJECTOR

Following the tragic explosion of *Challenger* in which seven crew members died, a new method has been devised for astronauts to escape from the Space Shuttle orbiter in an emergency. For the system to work, the orbiter must be in stable gliding flight in the lower atmosphere (6,000–9,000 metres). First, explosive bolts blow out the entry hatch on the Shuttle's mid-deck, and then a 4-metre long telescopic pole extends from it. Wearing their escape backpack, the astronauts take it in turns to slide along the pole and out into the air. The pole carries them clear of the craft, and their parachutes deploy automatically. For escape over water, the backpack includes a life raft.

M Hardy/Telegraph Colour Library

***Life rafts** are self-inflating and can carry up to 20 people. They are equipped with rations, water, medicines and fishing gear.*

Flotation device

When a ship goes down or when people are washed overboard, some kind of lighter-than-water support is essential. The simplest survival aid is a life-vest that is filled

Royal Navy Photograph

***The LR5** is used by the British Navy to rescue crewmembers from disabled submarines. In an emergency, a special, inflated life-jacket (below) is used to surface freely from up to 180 metres.*

with foam and worn like a waist-coat having straps to secure it.

This stops a person from actually sinking but it does not hold the face of someone who is unconscious clear of the water. For this reason, a life-jacket, although bulkier and less comfortable, is much safer. It fits over the head and is inflated either by blowing air in through a short pipe or by releasing pressurized gas from a gas bottle inside. Military versions inflate automatically when a special sensor detects water.

Survival at sea

For long-term survival, and even for short-term survival if the sea is very cold, a life-raft offers the greatest advantages of all. It keeps its occupants relatively dry and provides for the stowage of food, water and equipment such as a radio transmitter and flares. Inflation is rapid and automatic by way of built-in gas canisters.

A totally different vessel is needed for workers trying to escape from a burning offshore oil rig. As the flaming oil spreads out across the water it turns the surface of the sea into a hot inferno from which no ordinary rubber and canvas lifeboat could offer protection.

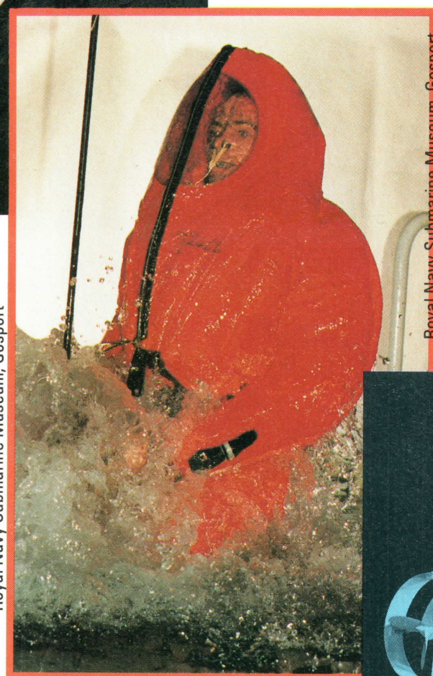
Fireproof capsule

The only way out then is with a fireproof survival capsule that can be lowered into the sea from the side of a rig. Each sealed metal capsule can hold up to 14 men and is self-propelled to enable it to be steered clear of the fire and within reach of rescue vessels.

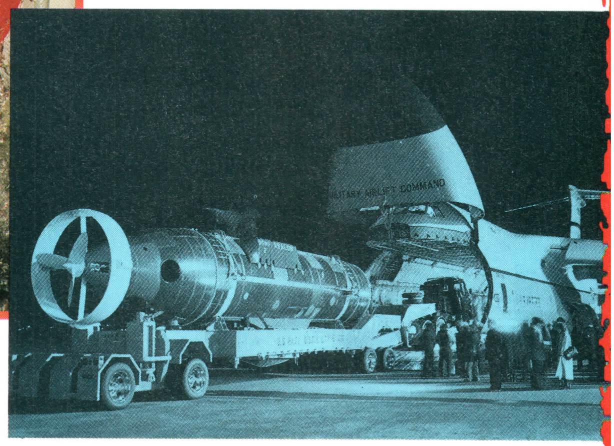
Deep-sea divers

Divers who may be working deep under the sea when an oil rig or offshore platform has to be evacuated also need a means of escape. They cannot simply come to the surface unprotected or they will suffer the excruciating and often deadly condition known as the 'bends'. (This happens when dissolved gas in the diver's blood expands to form bubbles as the outside pressure drops too rapidly.) Normally, divers spend up to several days in a decompression chamber after long periods deep underwater. But in an emergency, a special, reinforced lifeboat, containing a decompression chamber, is lowered down so that the divers can rapidly get away from the danger area.

Escape from damaged or crippled submarines is especially dangerous because of the potentially huge water pressure outside the vessel. A submarine can get into difficulties, for example, if its propeller becomes fouled or its hydroplanes



Royal Navy Submarine Museum, Gosport



Royal Navy Submarine Museum, Gosport

***The US Navy's DSRV** – Deep Sea Rescue Vehicle – being loaded into an Airforce C5 during a training exercise to rescue stranded submariners.*

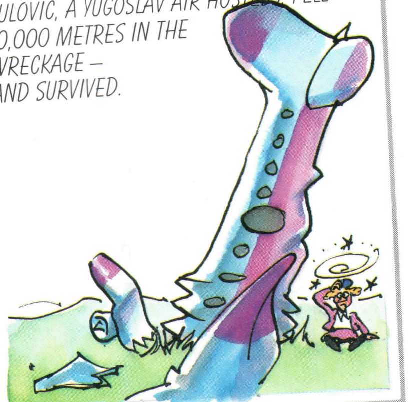
Quadrant Picture Library

***Inflatable chutes** are the standard escape device for civil airliners – passengers slide down to safety.*

Just amazing!

FALLEN ANGEL

WHEN A DC-9 AIRLINER WAS BLOWN UP IN MID-AIR IN JANUARY 1972, VESNA VULOVIC, A YUGOSLAV AIR HOSTESS, FELL 10,000 METRES IN THE WRECKAGE – AND SURVIVED.



Paul Raymonde

Gamma/Frank Spooner Pictures

***The Shuttle** escape hatch provides a means of escaping from the craft, should it become disabled. Another escape procedure involves the use of an escape pole (below). Much crew training since the Challenger tragedy has centred on ways of surviving possible future catastrophes.*

Gamma/Frank Spooner Pictures

are damaged so that surfacing is impossible. Or, during a conflict, a submarine can be crippled by an enemy mine or torpedo.

Once the vessel has settled on the seabed, its crewmembers have one of two options. In fairly shallow waters, they can try to escape from the emergency hatches and swim to the surface. At greater depths, a radio buoy has to be sent up to transmit an emergency signal.

A surface vessel or a second submarine may then come to help carrying a small rescue submersible. One type used by the British Navy, known as LR5, is lowered into the water from the ship and then manually steered to its target.

Submersibles

A metal funnel underneath, called a transfer skirt, fits securely over the emergency hatch of the sunken sub and provides a way for crewmembers to transfer to the submersible for their journey back to the surface.

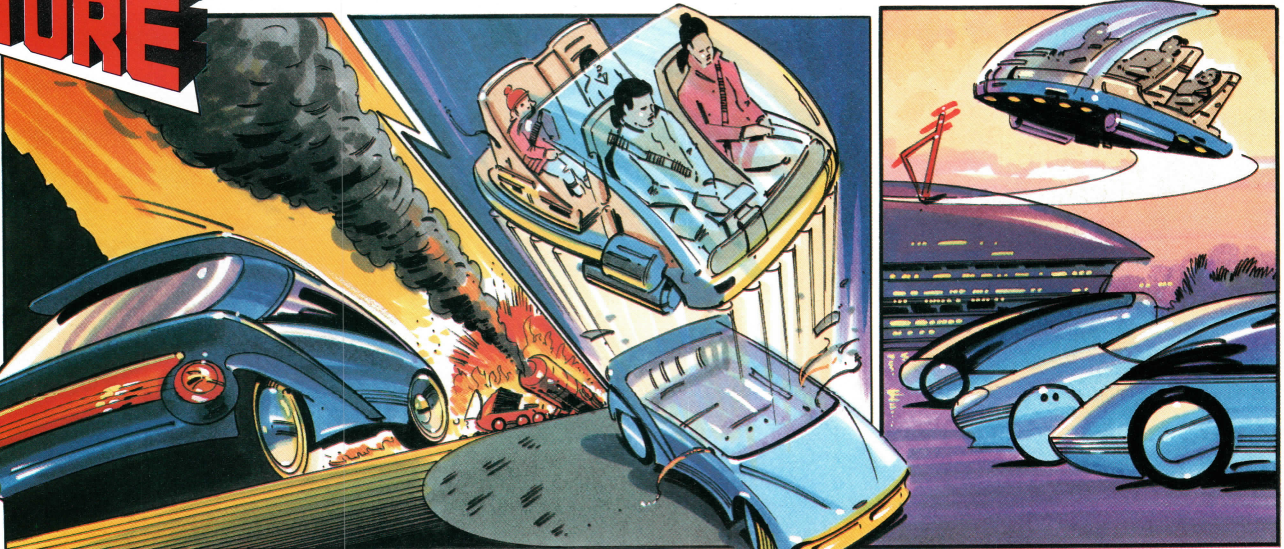
The US Navy employs a deep submergence rescue vehicle (DSRV), which is carried to the scene of the emergency on the back of another submarine. Like the LR5, it descends and links up with the emergency hatch of the sunken sub via a transfer skirt. Up to 24 people can escape at one time in the DSRV, which continues to travel back and forth until all of the crew is rescued.

Submarine systems

Although it has performed exercises with rescue vehicles, the British Navy has concentrated its efforts on developing an escape system for crewmembers of disabled submarines. This uses a special life-jacket that looks like a large hood and is secured to the crewmember's waist. Entering the escape tower, he plugs into an air-supply socket to inflate the life-jacket. Once the chamber is flooded it is opened and he simply rises freely to the surface, from depths of up to 180 metres, breathing normally as he goes. This system is not, of course, without its dangers. Rising freely from depths of 180 metres exposes the submariner to the 'bends' and nitrogen narcosis (a poisoning effect that results in dizziness or sickness).

INTO THE FUTURE

AUTO-EJECT SYSTEM



Joe Lawrence

▲ Approaching danger, the car of the future will be equipped with an intelligent escape system that will sense when a serious impact is unavoidable.

▲ The roof section will be jettisoned and tiny rockets installed in the ejector seats will fire, taking the occupants up and away from the scene of danger.

▲ The self-steering, rocket-powered seats will fly the occupants to safety where they will take directional instructions from the driver and land where required.

FIGHTING FIRE

FIRE IS STILL THE GREAT destroyer. But armed with the latest fire-fighting equipment and fire-supressing chemicals, Man now stands a better chance against this formidable natural enemy.

The most commonly seen fire-fighting appliance is the water tender. Equipped with a pump and 9- or 14-metre ladder, it carries over 1,800 litres of water. At the scene of an emergency, firemen immediately look for the nearest fire hydrant. In some countries, including Great Britain, its position is indicated by a yellow plate bearing an 'H'.

Water supply

A standpipe (a vertical pipe, in which water rises) is fixed to the hydrant and a hose is then connected to this to provide an unlimited supply of water. In country areas, water may be pumped out of

London Fire & Civil Defence Authority; Rex Features Ltd

***Fire spreads rapidly** through a skyscraper, leaping from floor to floor along service ducts that carry wiring, plumbing and air conditioning. Firemen must carry their own supplies of oxygen (above) so that they do not inhale toxic fumes or smoke.*

PUTTING OUT CHERNOBYL

When Reactor 4 in the nuclear power station at Chernobyl, in the USSR, exploded in April 1986, it started an horrific fire. At first local firemen tried to douse the flames with water. But the intense heat of the burning reactor core – up to 2,700°C – instantly turned the water to radioactive steam that rained down on the fire-fighters. In the end, the fire was only put out when helicopters dropped 5,000 tonnes of sand, clay, lead and boron on to the blazing power station. Radiation levels were so high that each pilot was only allowed to fly 22 missions.

David Hodgson/Telegraph Colour Library

An asbestos suit, *coated with aluminium, allows a fireman to get to the heart of a blaze – in this case on an oil rig in the Caspian Sea.*

Gamma/Frank Spooner Pictures

a nearby pond or stream. The supply in the tender is only used as a last resort.

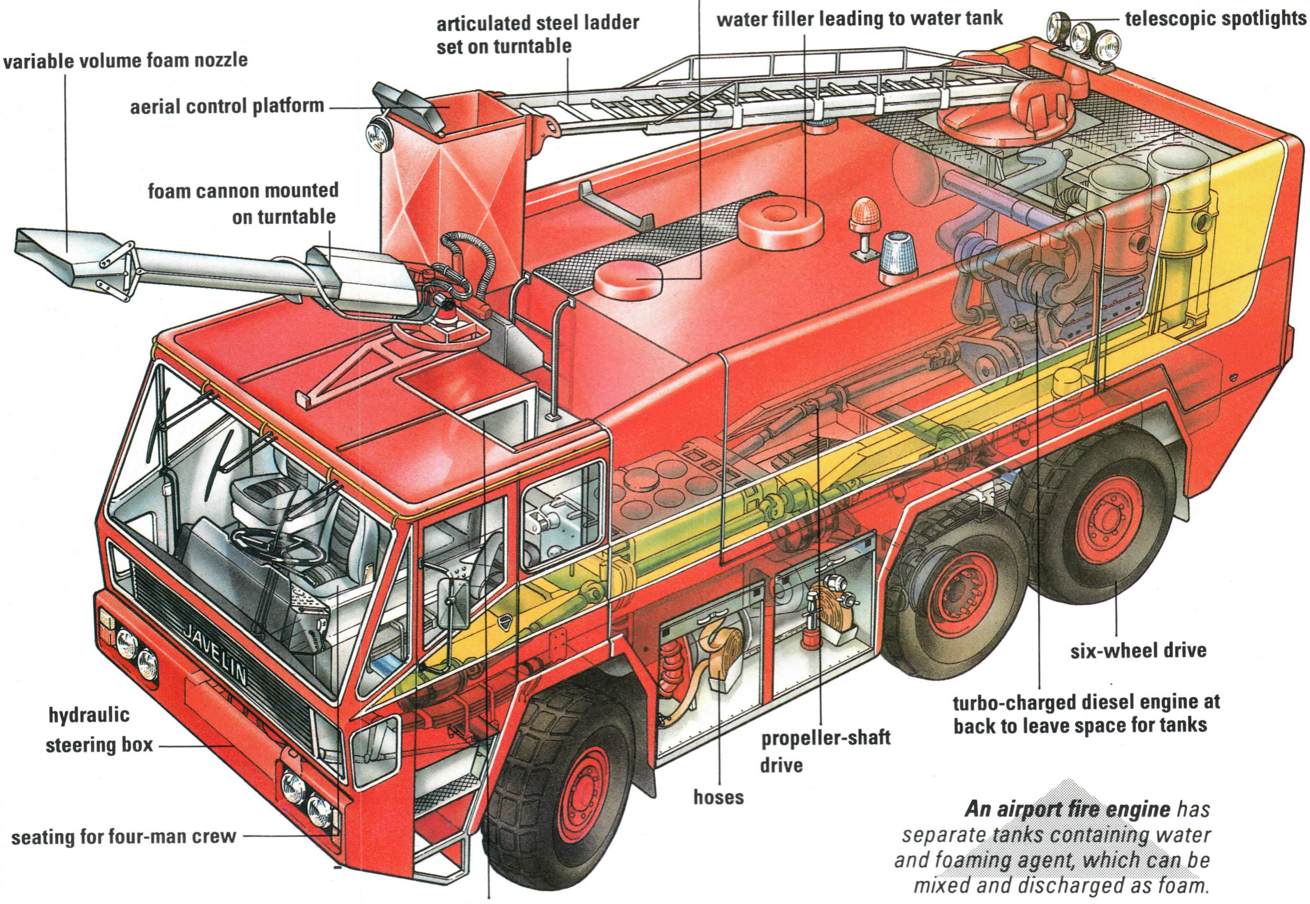
Another standard appliance, the turntable ladder, can rotate and extend to a length of 30 metres. From the top of the ladder, a fireman is able to spray water down on to the flames below or to rescue people trapped high in a multi-storey building.

A hydraulic platform, in some cases, may be called upon instead. This has a long, powerful arm, capable of bending at different angles, with a cage at the end. Up to four adults can fit in the cage at once, while an operator, either on the ground or inside the cage itself, can direct a jet of water through a large attached nozzle.

Smaller vehicles available to the fire service may carry cutting gear, winches and carbon dioxide gas or dry powders (used as an alternative to water or foam in, for example, electrical fires). All vehicles are fitted with flashing blue lights, a two-tone siren

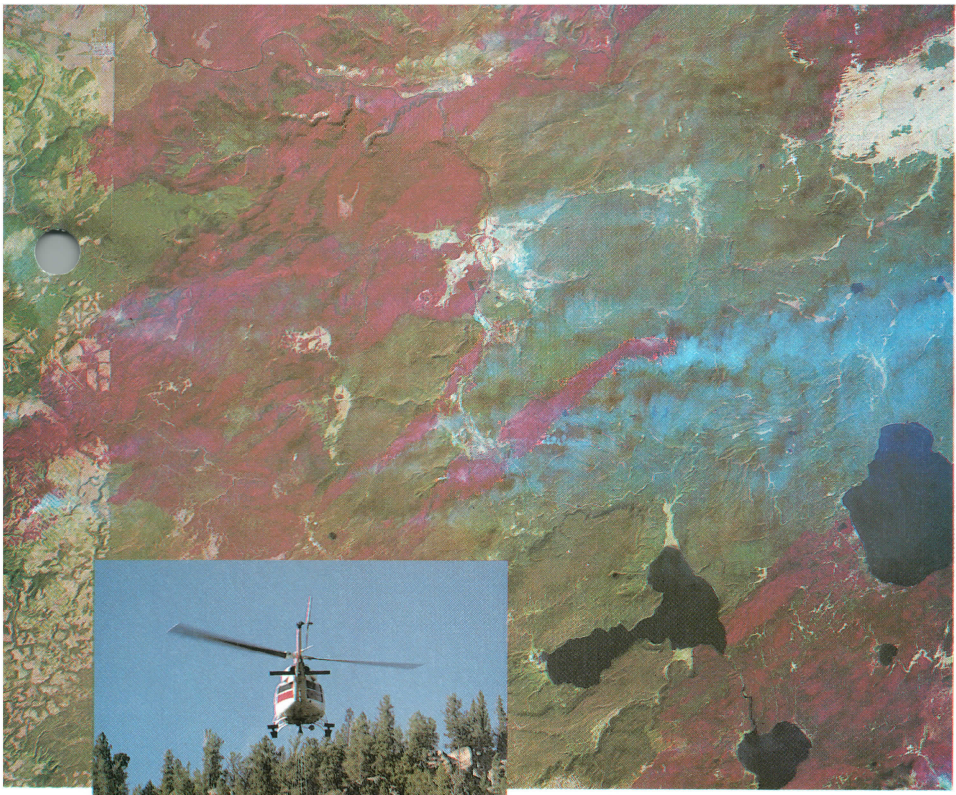
Foam *sprayed on to a burning aeroplane floats on the surface of the burning fuel and so smothers the flames. The foam is generated when air sucked in at the side of the hose nozzle aerates a fast-moving stream of foaming agent and water.*

Airport Foam Tender



An airport fire engine *has separate tanks containing water and foaming agent, which can be mixed and discharged as foam.*

John Houghton



Earth Observation Satellite Company, Lanham, Maryland, USA

***The Yellowstone Park** forest fires in 1988 were the largest fires ever known in the USA. This image taken by satellite Landsat 5 from a height of 705 km shows burned areas as magenta, fires as orangey-brown and smoke as blue.*

Alan & Sandy Carey

***Helicopters** were used to scoop up water with special buckets (below) from lakes within Yellowstone Park and drop their load on smaller fires as they broke out.*

and a radio to keep in constant touch with central control.

The call from the regional control centre to a local fire station gives details of the fire, its location and the appliances that are needed. At a very large fire, a mobile control unit may be set up to co-ordinate resources and provide a radio link with central control. The officers in the control unit decide on fire-fighting tactics, allocate jobs to the appliance crews, and arrange for relief personnel, if required.

Foam tenders

Fires that involve burning oil or petrol have to be treated in a special way. These are the kinds of fires that start at the scene of road, rail and aircraft crashes when fuel tanks are ruptured and explode. Since the still-burning oil or petrol would simply float to the surface of any water that was sprayed on to it, foam is used instead. The foam acts as a blanket, smothering the fire by preventing fresh oxygen in the air reaching it.

All water tenders carry a small quantity of liquid foam in drums, which is mixed with air as it passes through the hoses. Nozzles called monitors can be set up on the ground to shoot out arcs of foam over 20 metres high. If larger quantities are needed, specialized foam tenders are sent to the accident scene. These are equipped with a huge fan that can blow foam down a wide flexible pipe in order to reach inaccessible places.

Every major airport has its own fire-fighting appliances, including large foam tenders, in a building close to the runway. Even in the event of a minor incident where fire has not actually broken out, a plane may be sprayed with foam as a precautionary measure.

Researchers are trying to develop an additive to aircraft fuel that will prevent it exploding during an accident. A chemical known as Avgard

HIGH-TECH PROTECTION

Computer programs that simulate the progress of fires in buildings are used to reduce the risk of a real one spreading. Information on rooms and exits, furnishings and the location of occupants is fed into the computer. The program shows how quickly a fire will take hold, and other details, such as where best to position fire doors to stop it spreading.

***Fire fighters** protect poles carrying power lines through Yellowstone Park from an approaching fire by wrapping the bases with foil.*

Alan & Sandy Carey

TROUBLESHOOTERS – TO PUT OUT OIL-RIG FIRES

Rex Features Ltd

Tackling major fires and blow-outs at oil rigs is a task for specially trained teams of troubleshooters. A legend in this business is the Texan Red Adair, seen here tackling an explosion on the Piper Alpha oil rig in the North Sea that killed 167 men in 1988. His company, whose motto reads 'around the world around the clock', deals with around 30 serious oil-rig accidents each year. In one incident, he and his men put out 16 wells burning on a platform in the Gulf of Mexico by building special rafts to get them within 100 metres of the blaze, so they could deluge it with water.

has proved promising in trials. At the same time, work is going on to make seats and on-board equipment more resistant to fire and less likely to give off toxic fumes when burning.

After a long period of drought, the smallest spark is enough to set huge areas of forest-land ablaze. In the summer of 1988, Yellowstone National Park in Wyoming, USA, was parched through lack of rain. In August, lightning started a number of forest fires that quickly spread, fanned by gusts of wind. Suddenly, the situation was out of control.

Firelines

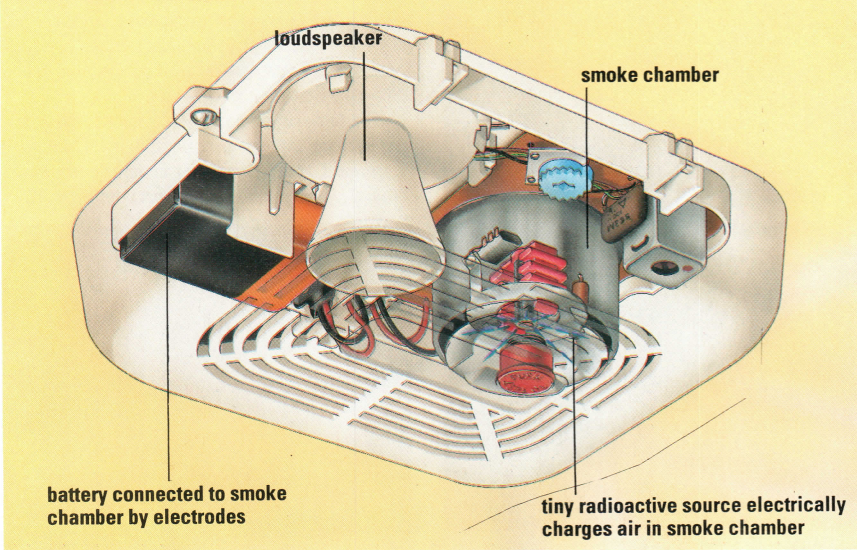
To put out a major forest fire with water is virtually impossible unless heavy rain falls. The only effective approach is to try to confine the damage to a certain area.

In some cases, the fire-fighters at Yellowstone felled broad strips of forest to deny the approaching fire a fresh supply of timber. Making these firelines also involved removing the top layer of soil which was rich in imflammable, partly-decayed wood. As a final measure, backfires were lit on purpose to burn out the area between the firelines and the oncoming blaze.

'Spot fires' were another problem for the 9,500 workers trying to quell the Yellowstone inferno. These were started by branches or other burning debris, carried by the wind from a major fire to a nearby region of untouched forest. By the time the Yellowstone fires died down, in October 1988, around 400,000 hectares – almost half the park's total area – had been burnt.

***The alarm** in an ionization smoke detector is set off when smoke from a fire reduces the electric current in a special chamber in the detector.*

Ionization Smoke Detector

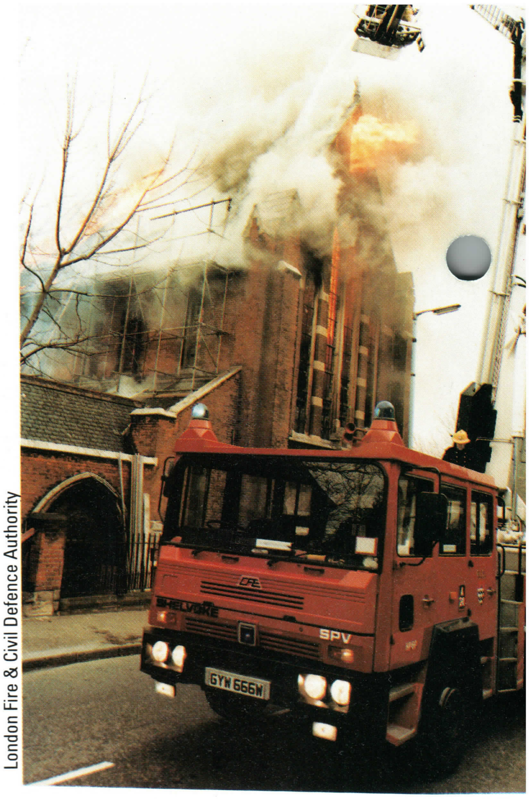


Steve Cross

Blow out

The moment every oilman fears is when the drill bit of a rig unexpectedly breaks through into an underground reservoir of high-pressure gas. In an instant, the gas forces its way up the drill casing to the surface where it may lead to a 'blow out'. Any spark or naked flame near to the gas then causes it to erupt in a devastating fire that can burn for days or even weeks.

On land, a common way of tackling drill-rig fires is literally to blast away the top of the well. While hoses damp down the flames, an explosive charge is gently lowered from a boom until it is about 3 metres above the well-head. The charge, which is remotely detonated, blasts gas and oxygen away so leaving the fire with nothing to feed on – thus the fire is extinguished. The final step is to cap the well-head with a valve to prevent further gas from leaking. Fires on oil platforms at sea are even more difficult to control. Fire-fighting ships pump out massive jets of seawater to subdue the flames. A team may then attempt to cap the leaking gas.



London Fire & Civil Defence Authority

***A hydraulic platform** with three booms can be operated in very confined spaces – it will even go over obstructions and down the other side.*

Just amazing!

UNFORGETTABLE FIRE

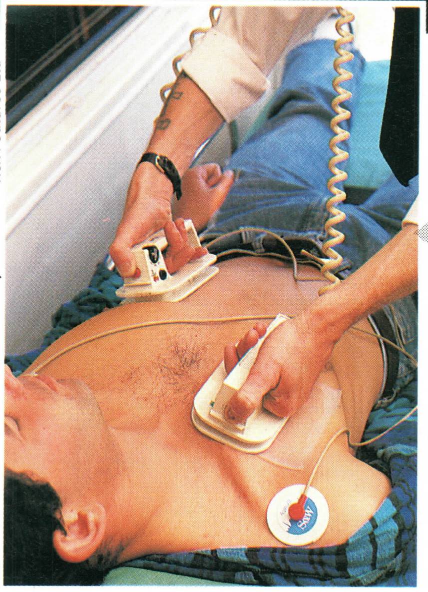
IN 1982, A FOREST FIRE IN BORNEO SPREAD OVER 36,000 SQ KM, DESTROYING 13,500 SQ KM OF WOODLAND. IT RAGED UNCONTROLLED FOR AN INCREDIBLE 10 MONTHS.

Paul Raymonde

EMERGENCY SERVICES

Rex Features Ltd

Cutting equipment was used to reach the injured and clear the track after a rail disaster at Clapham Junction, London, 1988.



Adam Hart-Davies/Science Photo Library

A defibrillator is used to deliver a controlled electric shock to a patient in order to restart his heart when it has failed.

TWO CARS HAVE COLLIDED head on. One man is lying on the roadside covered in blood. Several others are trapped in the wreckage, unconscious and badly injured.

Within minutes, a passer-by has phoned the emergency services and given details of the accident and its whereabouts to the control officer at the local ambulance headquarters. From here, radio instructions go out to the ambulances nearest the scene of the accident and the rescue mission begins.

Front line ambulances, used for accidents and emergencies, are packed with essential equipment for reviving patients and keeping them alive on their high-speed journey to hospital. Besides blankets, dressings and stretchers, the ambulances carry:

- suction apparatus to clear breathing passages
- resuscitators to force oxygen into the lungs of a person who has stopped breathing
- splints to support broken limbs
- anaesthetic gas

On arrival at the scene of an accident, the ambulance crew has to assess which of the casualties needs most urgent attention. Anyone who is not breathing, or is having difficulty breathing must be seen to immediately. An aspirator is used to suck blood from the mouth and the passage to the lungs. Then a plastic tube is inserted down the

LIFEBOAT EQUIPMENT

Liferafts, inflatable dinghies, floodlights, a loudhailer system, stretchers, lifelines, fire-fighting and oxygen equipment, boathooks, food provisions and parachute flares (that illuminate the area around the lifeboat at night) – all these make up just some of the equipment that a lifeboat carries.

When a ship is stuck on rocks and a lifeboat cannot get alongside it, a breeches buoy is used. A rocket-propelled gun fires a line from the lifeboat to the ship. Then a thicker rope is pulled on board and stretched between the two vessels. The breeches buoy is a seat that is slung beneath the rope, allowing one person at a time to be transferred to the lifeboat.

Rex Features Ltd

Larry Mulvehill/Science Photo Library

***Communication** is essential to ensure the relevant rescue services attend an accident. An ambulance crew (left) often contacts its destination hospital for guidance.*

throat to keep the airway open. Finally, an oxygen mask is fitted over the person's face. The next priorities are unconscious casualties and those who are bleeding severely.

Some ambulances have a heart monitoring unit on board. The shape of each pulse appears on a small screen, while a permanent record can be plotted out on a continuous strip of paper. If a casualty's heart has stopped beating, there will be no pulse. In this case a defibrillator (linked to the monitoring unit) may be used to try to restart their heart.

Shock treatment

The defibrillator consists of two hand-held plastic 'paddles', with metal discs at their base. Applied together, these deliver a momentary electric shock across the casualty's chest. If the first shock fails to start the heart beating, further attempts are made using stronger currents.

If a casualty is losing a lot of blood, there may not be enough fluid left in his or her circulatory system for the heart to continue pumping oxygen-rich blood to essential organs, such as the brain. Donor blood has to be carefully matched to the blood type of the recipient. This can only be done at hospital where supplies of every blood type are held. To keep the casualty alive until then, the ambulance crew

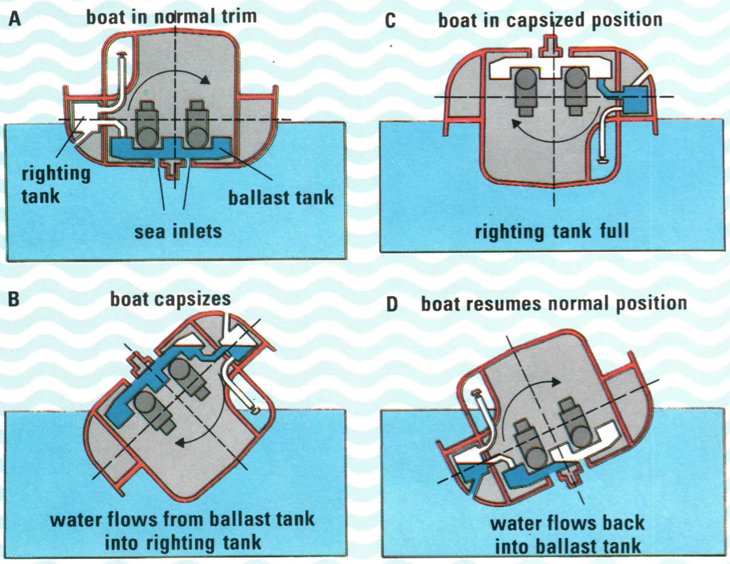
ZEFA

***Helicopters** are often invaluable when other services are rendered helpless – for searching inaccessible terrain or for lifting people from the sea.*

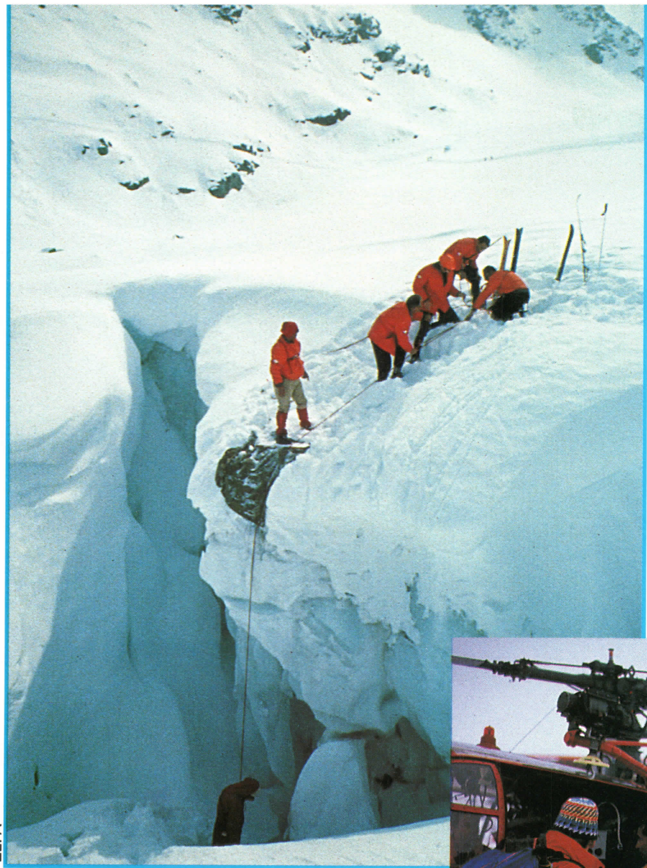
THE SELF-RIGHTING LIFEBOAT

Modern lifeboats are designed to be self-righting. Some – including inshore rescue craft – are fitted with inflatable airbags mounted on the stern of the craft. The bags are slightly off-centre so that the boat is righted immediately if it is knocked over. Others are fitted with the Oakley self-righting system.

The Oakley system consists of a ballast tank in the bottom of the hull that is filled with water. A second tank – the righting tank – is mounted on the port (left) side. As a boat capsizes water rushes from the ballast tank in to the righting tank. The weight of the water either checks the turning movement or turns the boat through 360° back to upright position. Then the water flows back from the righting tank to the ballast tank. The whole operation takes 5–8 seconds, and is controlled by a system of specially designed valves.



RNLI



ZEFA

Swiss mountain rescuers *pull an injured skier from a crevice. Rescue workers – often volunteers – are experienced climbers and skiers familiar with the local area.*

Injured skiers *and climbers are sometimes unable to be helicopter lifted without ground assistance. They may be unconscious, or buried in snow after an avalanche.*

Gamma/Frank Spooner Pictures

administers a kind of artificial 'blood'. This is a clear liquid that substitutes, temporarily, for natural plasma – the colourless, watery substance that blood cells float in.

Mountain rescue

When people get injured or lost in remote highland areas, the nearest mountain-rescue team is alerted. The team consists of volunteers of expert climbers with a good knowledge of the local mountains.

Once the team leader has been briefed by the police, he or she contacts the rest of the team by phone or radio bleeper. The team members assemble their equipment, which includes ropes, climbing gear, stretchers and first-aid materials, then head towards an arranged meeting place. Meanwhile, a police car drives as close as possible to the scene of the accident to act as a communications centre and base for operations. All mountain-rescue teams carry portable two-way VHF radios for keeping in touch with the control base.

If someone is injured, the team leader has to decide on the best method of rescue. In some cases, a helicopter may be called for. But if weather is bad or visibility poor, the rescue team must try to reach the casualty on foot. Someone who is not badly hurt may be carried down steep rocks on a rescuer's back using a special harness called a Tragsitz. Otherwise, the injured person is tied to a stretcher and lowered by rope. Most stretchers consist of a strong, lightweight metal frame set on ski runners.

Animal sense

When people are missing in the mountains, search dogs are especially valuable. These are trained to follow human scent trails and will find articles like rucksacks and pieces of clothing. In partnership with its handler, one dog may be more effective than twenty human searchers, particularly at night or in bad weather.

Large search and rescue operations, such as that following an air crash, may also involve helicopters, supply lorries and 4 wheel drive vehicles equipped as ambulances and communications centres.

In coastal areas, the coast-guard forms a fourth emergency service, in addition to those of police, fire and ambulance.

Mayday

Coast-guard rescue centres are manned 24 hours a day. Channel 16 VHF – used internationally for distress calls – is monitored continuously. Local frequencies used for communicating with ships, aircraft, lifeboats and coast-guard vessels will also be monitored.

Planning a search and rescue at sea is more complicated than on land because tides, currents, and wind have to be taken into account. For this reason, computers are being used more and more in coast-guard operations. Given a vessel's last reported position together with prevailing sea and weather conditions, a computer can quickly isolate the area to be searched.

Fax machines are used by the coast guard to send and receive copies of weather charts, maps (showing, for example, the location of an oil spill), and ship cargo details. Computerized telex, by which mes-

Rex Features Ltd

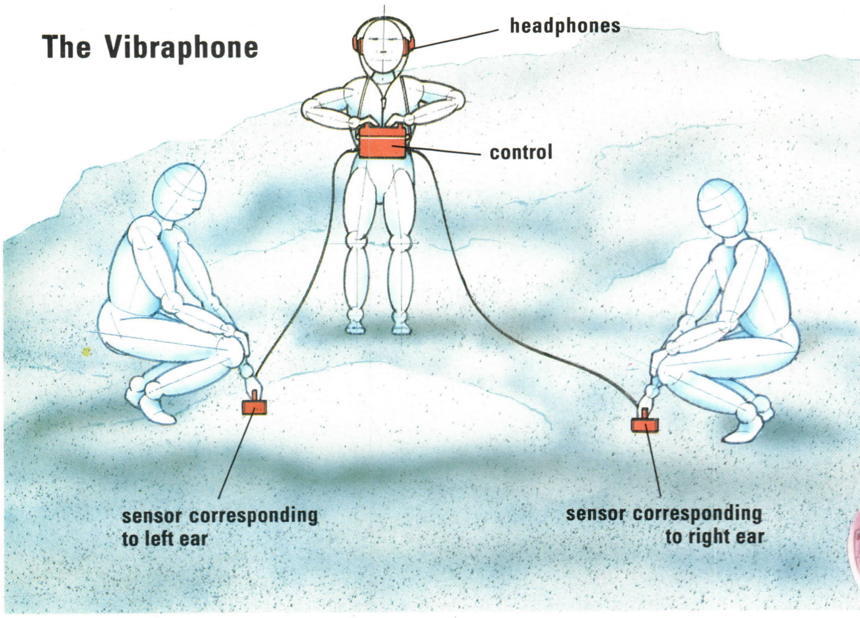
Sniffer dogs, *with their highly developed senses of smell and hearing, are valuable aids in searching for people buried by snow or rubble. This one searches the rubble in the aftermath of the Mexican earthquake in 1985.*

Just amazing!

NEE-NOR, NEE-NOR . . .

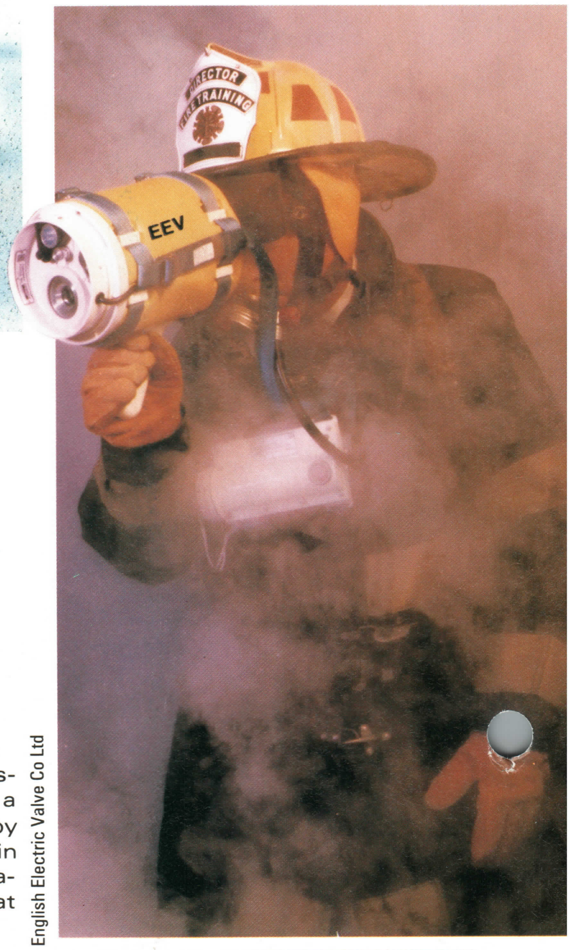
THE WORLD'S LARGEST AMBULANCE IS THE 18-METRE, ARTICULATED ALLIGATOR 'JUMBULANCE' CAPABLE OF CARRYING 44 PEOPLE.

Paul Raymonde



John Houghton

Thermal cameras *have lenses made of tiny cells that are sensitive to heat changes of 0.5°C. They 'see' heat pictures through smoke and flame and can pinpoint casualties, or the source of a fire, and relay the information via electronic signals back to a control centre.*



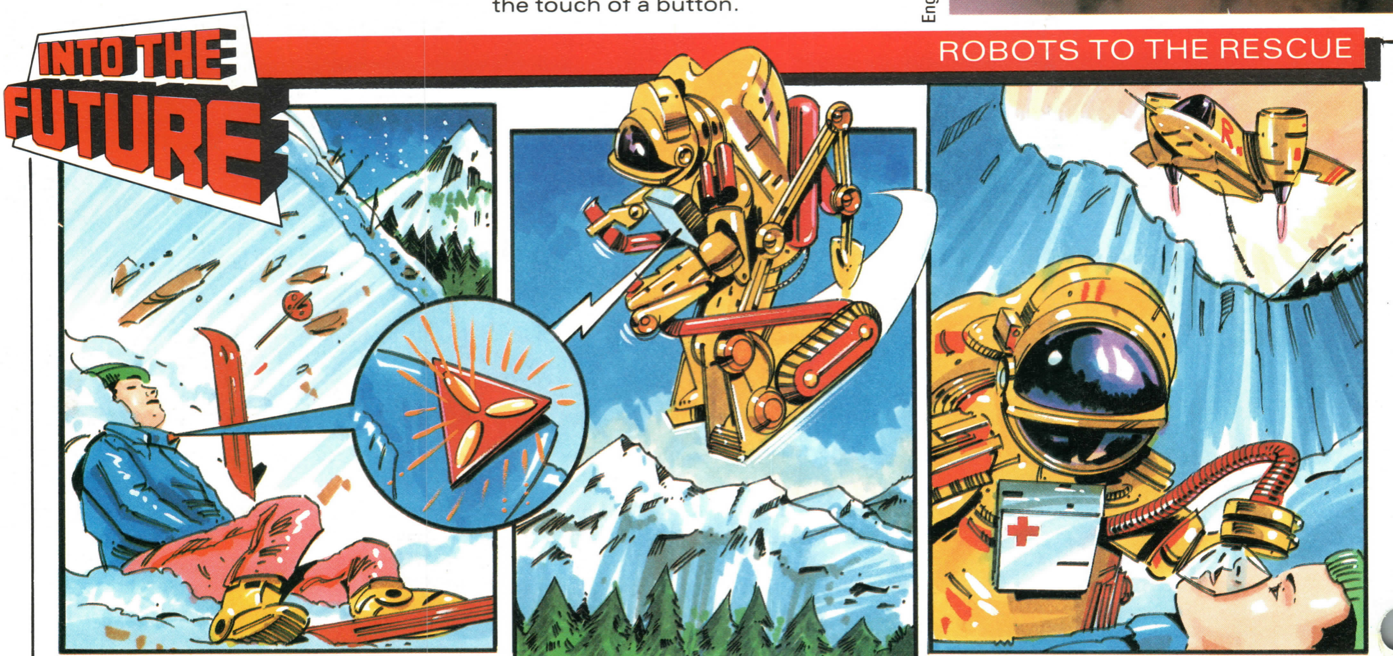
English Electric Valve Co Ltd

sages can be sent automatically, has also recently replaced ordinary telex.

Most coast-guard rescue centres are equipped with a VHF direction finder for locating a vessel from its radio signal. Two radio masts at different points along the coast provide cross-references, enabling a ship's position to be calculated.

If a vessel is far from shore, ships and coast-guard stations exchange clear messages via orbiting satellites. In 1979, an international organization known as *Inmarsat* was set up to manage a worldwide system of satellites for maritime communications. A message beamed up to one of these satellites from a ship at sea is relayed to a large dish aerial on land known as an earth station where it enters the telephone or telex network. The message can then be quickly routed to a coast-guard station that replies by the same system. If a ship is in difficulty it can transmit an automatic distress signal, via satellite, at the touch of a button.

Sound vibrations *transmitted through solids are detected by a vibraphone, which is used to find people who are buried alive. Sensors pick up and amplify (make louder) underground noises such as knocking, scratching or breathing. Each amplifier is connected to one headphone and noises also register on the control panel. The operator is able to direct his helpers to the spot because the sensor nearer the casualty will pick up a louder signal.*



▲ *Skiers of the future will carry tiny transmitters that will be automatically activated in an emergency – such as being buried in snow after an avalanche.*

▲ *A robot searcher, launched just after the avalanche, will fly to the distress signal given out by the transmitter, then carefully dig its way down to the trapped skier.*

▲ *Having found the skier, the robot will administer any emergency treatment that may be necessary while calling for the airborne rescue services.*

Joe Lawrence

Quadrant/Flight

The Harrier jump-jet, here on a rig to test the thrust of its Rolls-Royce Pegasus engine, has the unique ability to take off and land vertically. NASA's AD-1 (inset below) features a pivoting wing that reduces drag, so increasing speed and range.

NASA

VERTICAL TAKE-OFF

AIRCRAFT THAT CAN SWIVEL their engines or alter the shape of their wings have proven themselves to be formidable fighting machines. They offer the advantages of several ordinary planes.

Jump-jets, or vertical take-off and landing (VTOL) planes, combine the manoeuvrability of a helicopter with the speed of a high-performance jet. The best-known and most successful is the British Aerospace Harrier.

Air, taken in by the Harrier's single Rolls-Royce Pegasus engine, is compressed and then blasted out of four nozzles, two on each side of the aircraft. For take-off and landing, these nozzles are angled straight down to provide vertical thrust. Small air jets called 'puffers', at the tips of the wings and at each end of the fuselage, allow the pilot to stabilize the Harrier when it is hovering. Once the plane is off the ground, the nozzles can be gradually swivelled back to push the Harrier forward up to a maximum speed of over 1,160 km/h, or Mach 0.95.

VIFFing

While other fighters may be faster, the Harrier more than makes up for this by a technique called VIFFing (vectoring in forward flight). If another plane is chasing him during a dog-fight, the Harrier pilot can suddenly rotate the side nozzles from the fully back position through 180 degrees. This slows the jump-jet in mid-air far more rapidly than conventional air-brakes could, so that the pursuing plane overshoots. The Harrier pilot can then quickly turn the nozzles back through 180 degrees to give maximum forward thrust again and get on the tail of his enemy.

Short Take-Off and Landing (STOL) aircraft, by contrast with VTOLs, do need a runway — but a much shorter one than for a normal plane. This allows them, for example, to fly right into the heart of a city or mountainous terrain, where a long

landing strip would be extremely difficult to build.

STOL aircraft work by generating extra lift at low speeds. The Boeing C-14 transport plane, for instance, has its engines mounted on top and in front of the wings. This allows it to make use of a property known as USB, or Upper Surface Blowing.

Coanda effect

The C-14's wing flaps curve down behind the wings' trailing edges. This causes the jet exhaust gas blowing over the wings' upper surface to 'stick' to the flaps and so be directed almost straight down creating a powerful lift. To see this phenomenon known as the Coanda effect, in action, simply hold the back of a spoon under a running tap and notice the way the water closely follows the curvature of the spoon.

An alternative approach to STOL is that used in the American Bell XV-15 research aircraft. Known as a tilt-rotor, this employs propellers, instead of jets, mounted on engines that swivel at the wingtips to provide horizontal or vertical thrust.

Increased lift

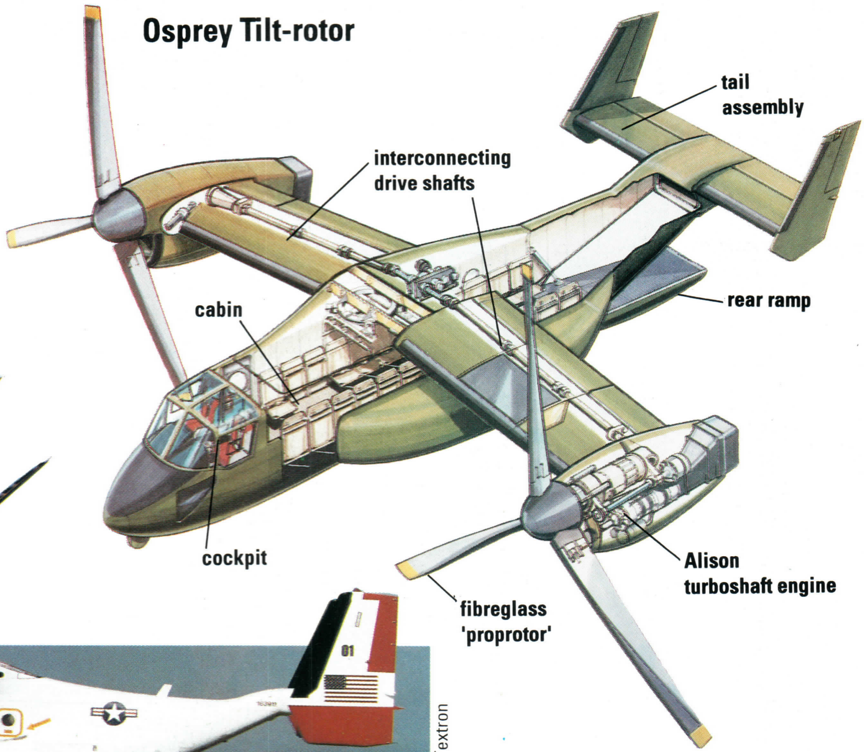
Wings that stick straight out give good lift at low speeds, while swept-back wings are more efficient for supersonic flight. With this in mind, a number of fighter planes have been developed that have swing-wings, which can be gradually angled back as the aircraft gathers speed.

The two-seater Panavia Tornado, which entered service in Europe in 1982, has wings that are connected to a rigid box inside the fuselage. Hydraulic jacks allow them to be moved backwards or forwards. At take-off, the Tornado's wings are spread out wide for maximum lift so that the plane can use a fairly short runway, despite its heavy load of missiles and full fuel tanks.

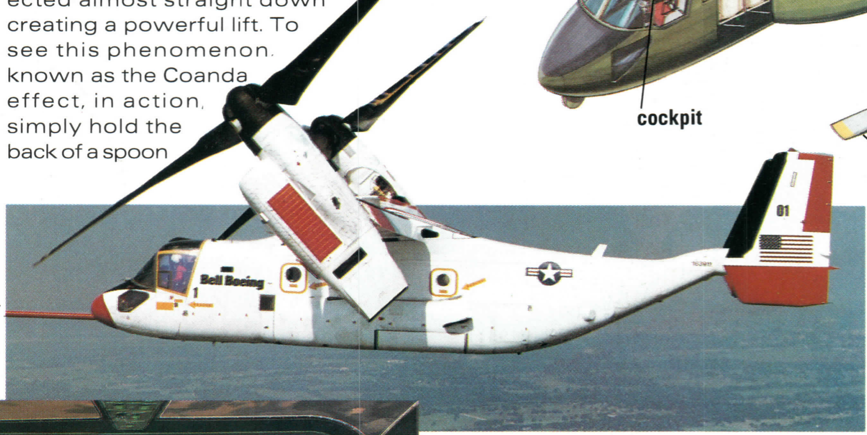
Reducing drag

As the plane flies faster, however, the increasing flow of air around the wings generates more and more lift. The pilot can then operate the swing-wing control, progressively sweeping back the wings to reduce drag as he throttles up to a top speed of 2,333 km/h, or Mach 1.9.

A different and much stranger looking kind of swing-wing plane, known as the AD-1, has been tested by NASA. This has a single wing that pivots like a scissor blade over 60°. Again, this reduces drag at high speed but is both lighter and simpler because there is only one swivel point instead of two.



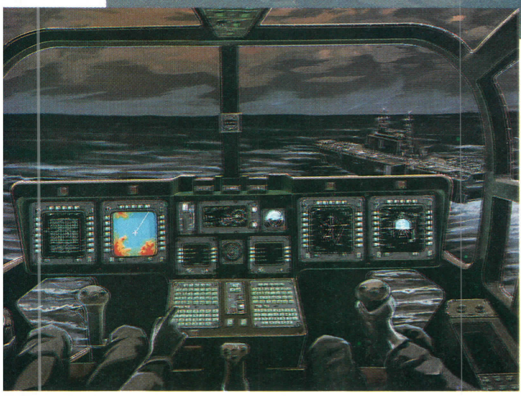
Bell Helicopter Textron



Bell Helicopter Textron

Bell Helicopter Textron

***The V-22 Osprey** features a tilt-rotor that allows it to hover like a helicopter and cruise in normal flight at 610 km/h.*



***Cockpit controls** in the Osprey change automatically from hovering to forward flight as the 'proprotor' swivels.*

Just amazing!

NIFTY MOVER

THE BRITISH AEROSPACE HARRIER JUMP-JET IS THE ONLY AEROPLANE IN THE WORLD THAT CAN TRAVEL BOTH FORWARDS, AT SUPERSONIC SPEEDS, AND BACKWARDS, AT 80 KM/H.

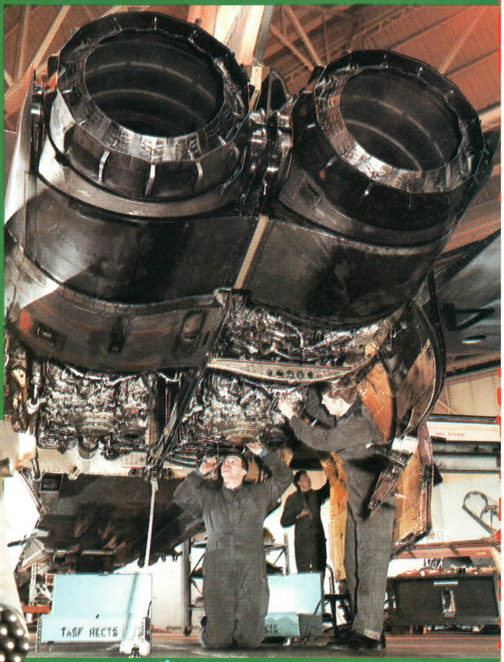
Paul Raymonde

***The wings** of the Tornado extend to provide the necessary lift to take off with a full payload of weapons and fuel.*

British Aerospace

AIRSPACE DEFENCE
DOGFIGHTERS
SPIES IN THE AIR

AERIAL WARFARE



RAF technicians *carry out post-flight checks on the Turbo-Union RB199 engines of an IDS Tornado after a day's training.*

The AH-64 Apache *ground-attack helicopter, armed with both 30 mm cannon and homing missiles, on a training exercise at the US army's Fort Hood.*

McDonnell Douglas Helicopter Co

AERIAL WARFARE TODAY takes place at supersonic speeds between aircraft carrying an incredible array of weapons.

In the front line of a nation's air force are its combat planes, made up of fighters and strategic bombers. Each of these consists of a weapons platform (the plane itself) together with the weapons system (missiles, bombs, etc) that it carries.

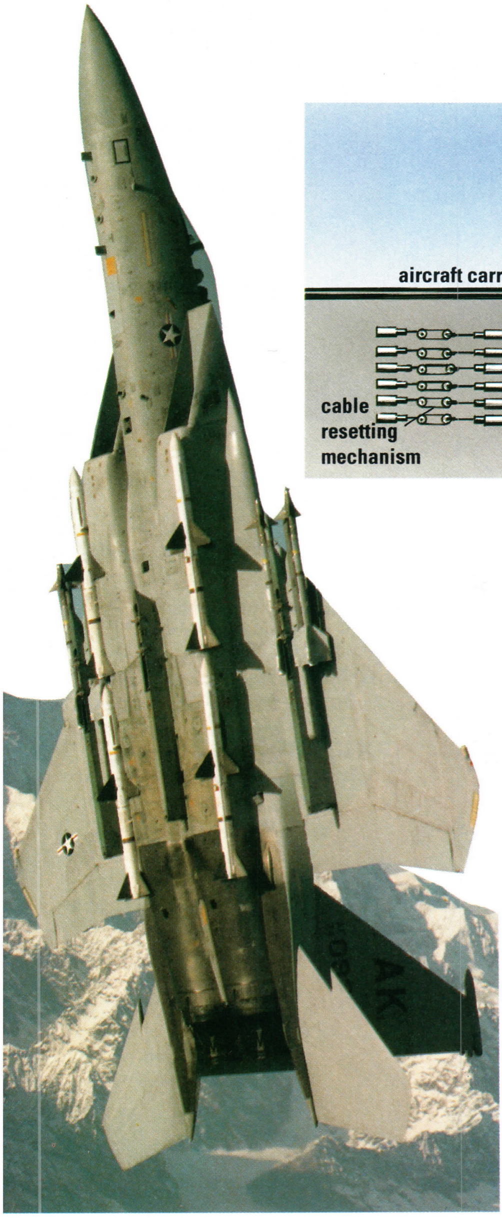
Less obvious, but no less vital, are other types of military aircraft used for reconnaissance, transportation and mid-air refuelling. Finally, modern aerial warfare would be impossible without support from a sophisticated network of communications equipment and radar tracking stations situated on the ground.

Interceptors

Most spectacular in their performance are the interceptors. These are used to engage enemy planes if they fly into friendly airspace. Russia's MiG-25, code named Foxbat, for instance, was built to intercept American B-70 Valkyrie supersonic bombers. Although not agile enough to be effective in dogfights, the MiG-25, loaded with 4 heat-seeking missiles, can reach the astonishing speed of 2,980 km/h – equivalent to 2.8 times the speed of sound, or Mach (after the scientist Ernst Mach) 2.8.

In due course, the Valkyrie programme was cancelled, but the fact that Russia now owned the fastest interceptor plane in the world meant that the US had to have an aircraft that could counter it. Thus it developed the McDonnell Douglas F-15 Eagle which, though slightly slower than the Foxbat, is one of the finest fighters ever built.

Whereas the role of an interceptor is purely defensive, that of a combat dogfighter is aggressive. This type of



McDonnell Douglas

FLOATING AIRFIELDS ON THE OCEANS

John Houghton

Aircraft carriers are mobile airfields from which attacks can be launched on other ships or at targets on land. One of the problems that carrier-based planes face is in taking off or landing since the runway is so short. To help them gain flying speed quickly, the aircraft is attached to a steam-powered catapult. The pilot opens his throttle wide and the aircraft, powered by its own engines and the catapult, accelerates down the flight deck. At the end of the runway, the aircraft disengages from the catapult mechanism and flies under its own power. To land, the pilot releases an arrester hook from the rear of the plane. This catches a damped wire stretched across the landing strip (above), causing the plane to slow from about 240 km/h to rest in about 60 metres.

***The F-15 Eagle,** pictured accelerating vertically with a full complement of air-to-air missiles, is one of the most powerful fighters in service.*

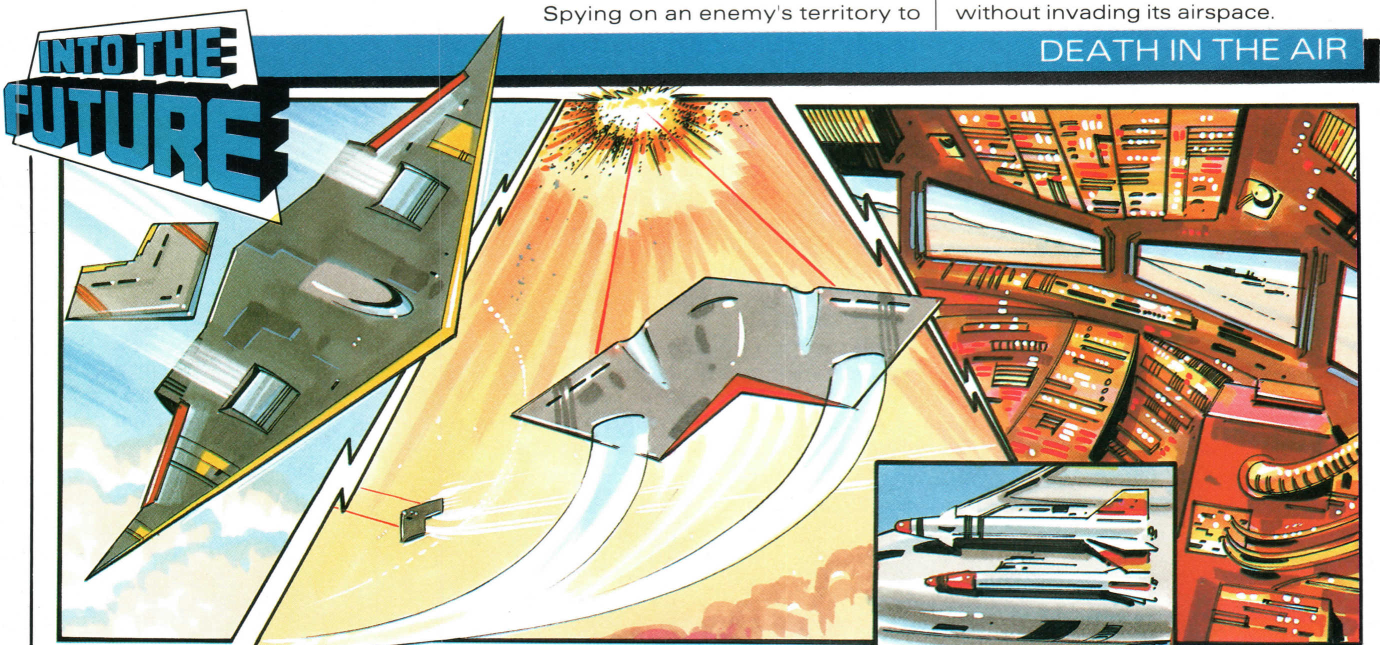
which is a modified version of the commercial Boeing 707. Using a rotating, saucer-shaped radar scanner on top of its fuselage, the Boeing AWACs can spot even low-flying enemy aircraft over 300 km away. It can, therefore, serve as an airborne command centre to co-ordinate and direct the counter operations of friendly planes.

Spying on an enemy's territory to discover the whereabouts of ground forces and other targets is important before launching an attack. For this task, reconnaissance or 'spy' planes are used, fitted with high-resolution optical and infrared cameras as well as radar equipment.

Reconnaissance

Equipment known as Sideways Looking Airborne Radar, normally carried in a thin oblong box below the fuselage, literally gives a side-on radar view. This means that the spy plane can fly up and down friendly territory, watching the enemy without invading its airspace.

INTO THE FUTURE — DEATH IN THE AIR



▲ *Most military aircraft will have angular shapes, like Lockhead's F117 Stealth fighter, designed to confuse or even be invisible to enemy radar.*

▲ *The planes' weaponry will include hypervelocity missiles (HMVs), guided from the launch aircraft by laser and capable of speeds of Mach 4.5.*

▲ *Eventually, expensive-to-train and non-expendable human pilots may no longer be necessary as 'intelligent' computers and robots take the controls.*

Joe Lawrence

CIRCUS IN THE SKY

Richard Cooke

The Red Arrows' Parasol Break is just one of the team's many formations. The display takes 20 minutes and requires 6km visibility.

AERIAL ACROBATICS AND formation flying push both men and machines to their very limits. When the RAF's display team the Red Arrows performs, the aircraft may be only a wingspan apart while flying at speeds of up to 600 km/h. Only split-second timing stands between a perfectly executed stunt and disaster.

One of the first tasks of a Red Arrows newcomer is to become totally familiar with the team's high-performance jet — the British Aerospace Hawk.

Designed as an advanced trainer and ground-attack aircraft, the 12-metre-long Hawk is powered by a single Rolls-Royce Adour turbofan engine. This can propel the plane to a speed of 1,040 km/h (Mach 0.88) in level flight or 1,420 km/h (Mach 1.2) in a shallow dive, and to a maximum altitude of 15,240 metres. More importantly, the Hawk has all the essential features of a true aerobatic machine.

Modern aerobatic teams around the world often use jet trainers as their display aircraft. The reason is that these planes are purpose-built to

be responsive, agile and predictable in flight. The Hawk, for example, is very difficult to put into a spin by mistake. Only when the pilot throws the rudder fully over to one side will the plane spin at all and even then it will recover after a single turn when the controls are centralized.

Power-packed

Another requirement is that the plane should stand up to sudden sharp changes in speed and direction. It must be manoeuvrable yet rugged, and able to handle the differing degrees of G force. A force of 1G is the equivalent of gravity. A simple, 'human-engineered' cockpit with well laid out controls and a bubble canopy for maximum all-round vision are also important to the display team pilot.

The nine Red Arrows pilots are usually posted to the team for three years before returning to normal duty or flight instruction. Selection is based not only on flying skill, but on the pilot's ability to get on well as part of a tightly knit group.

Tony Stone Photo Library, London

Richard Cooke

***Pilots** experience massive amounts of G force during acrobatic displays. This is caused by the plane's high acceleration. To reduce the risk of black-out, Red Arrow pilots wear anti-G suits (above) which prevent the blood supply draining from the brain.*

Blood-rush

During a loop-the-loop and similar manoevres, an aerobatic plane and its pilot experience up to 7 G, or a force seven times stronger than that of normal gravity. Under these circumstances, the blood in a pilot's body tends to rush downwards away from his brain and there is a risk of him blacking out. To prevent this, all high-performance jet fliers wear anti-G suits. As the aircraft goes into a turn, the anti-G suit inflates tightly around the legs and stomach to prevent too much blood draining from the head.

Smoke trails

One of the most spectacular sights in formation flying is when the aircraft leave long curving trails of coloured smoke left in their wake. These are produced by smoke pods (originally designed in the case of the hawk, to house a 30mm Aden gun) situated beneath the plane's fuselage. The centre pod on a Hawk holds 227 litres of pure diesel fuel which makes white smoke when burned. Two smaller pods situated to the front and rear of the fuselage carry 45 litres each of diesel/dye mix – one for making red smoke, the other blue. The pilot selects the colour he wants by pressing one of three buttons on top

Tony Stone Photo Library, London

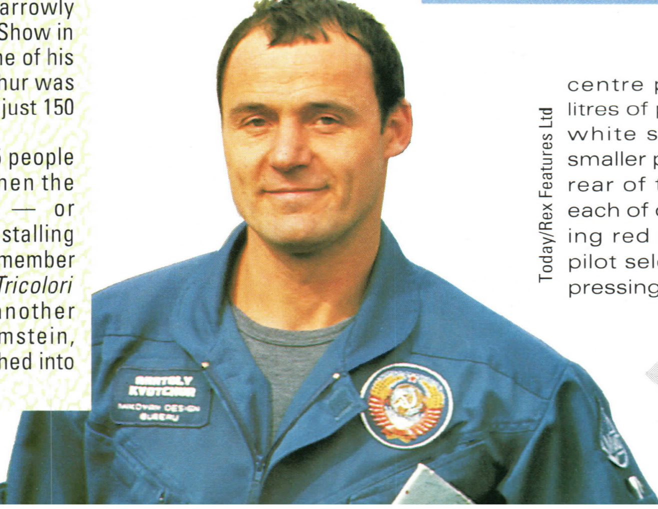
***The Blue Angels** are the USA's equivalent of the Red Arrows. Like the Arrows, they fly a specially adapted fighter – the F-A 18. Designed for both defence and attack purposes, the F-A 18 has a top speed of 1,915 km/h.*

DEADLY DISPLAYS

Quadrant/Flight

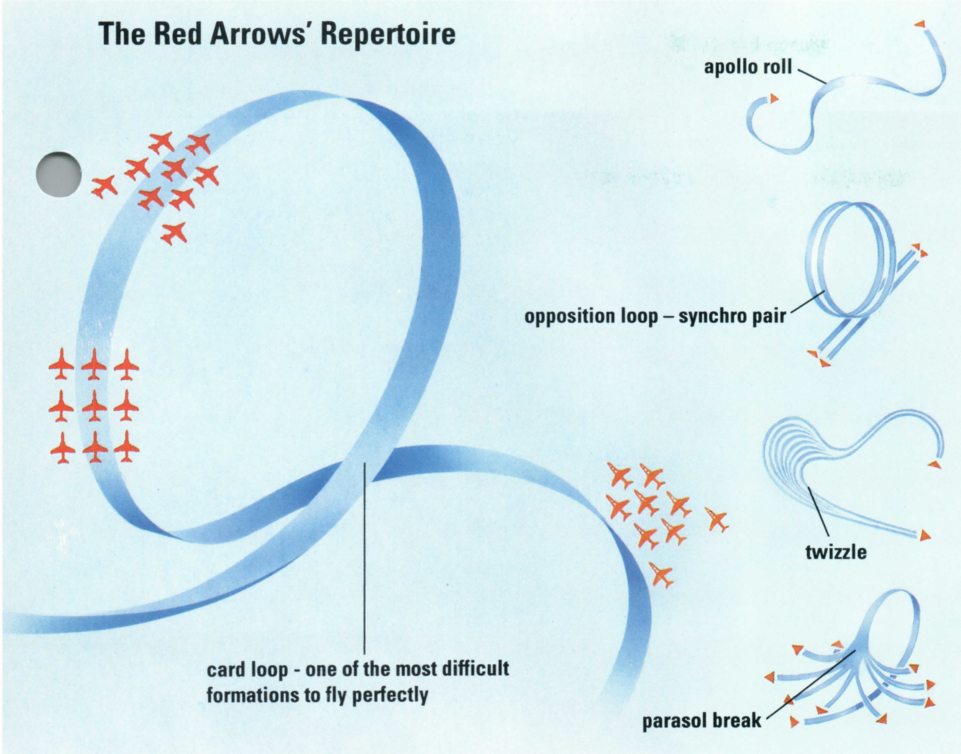
Soviet pilot Anatoli Kvotchur narrowly escaped death at the Paris Air Show in June 1989, when the right engine of his fighter burst into flames. Kvotchur was forced to eject at an altitude of just 150 metres.

At the 1973 Paris Air Show, 15 people were killed and 28 injured when the Russian-designed Tupolev — or 'Concordski' — crashed after stalling during a steep climb. In 1988 a member of the 10-strong Italian *Frecce Tricolori* team touched the wing of another plane during a display at Ramstein, West Germany. Three jets crashed into the crowd, killing 47 people.



Today/Rex Features Ltd

***Soviet pilot** Anatoli Kvotchur withstood up to 20 G when he ejected from his Mig-28 fighter at the Paris Air Show.*



To loop the loop, *a pilot has to gain sufficient speed and then pull back on the controls to bring the plane's nose sharply up. At this point, the pilot experiences a dramatic rise in G force – up to 3 or 4 Gs.*


John Carty

of the control column in the cockpit.

In an emergency, the pilot can pull on a handle to eject out of his plane. The canopy covering the cockpit has a continuous loop of narrow lead tubing built in that contains an explosive powder. Two detonators go off as soon as the ejection handle is released. These ignite the powder which then shatters the canopy. Less than a fifth of a second later, the pilot is shot out of the aircraft on his rocket-powered ejection seat. The pressure on the pilot reaches 20 G. Tall pilots, especially, risk smashing their knees on the way out or suffering whiplash as their heads are jerked down into their laps.

World-famous flying teams such as the British Red Arrows, the Italian *Frecce Tricolori* and the United States Navy's Blue Angels have each developed their own repertoire of formations and aerobatic stunts that they vary slightly from year to year. For instance, during the Red Arrows' full 20 minute programme more than a dozen different group formations are flown. Two aircraft, known as the Synchro Pair, also perform dual stunts.


Richard Cooke

Tony Stone Photo Library, London

An engineer *fills a Hawk's tanks with red dye. Frecce Tricolori (below) have green, red and white smoke trails – the colours of the Italian flag.*

Smoke trails *are also used to create a dramatic effect during parachute displays. Dye canisters are strapped to the parachutists' legs.*


Gamma/Frank Spooner Pictures

Allsport

WEIGHT-WATCHERS

Every astronaut's training programme involves preparation for weightlessness. The trainee crew of a space shuttle are taken up in a high-altitude aircraft, which dives along specially calculated curving paths. For up to a minute, the astronauts experience conditions that are close to zero gravity. They float around, bouncing off the plane's well-padded interior. Astronauts are also trained in centrifuges – machines that revolve at very high speed, which subject them to high levels of G force.

Allsport

Free-fall *parachute displays can be just as spectacular as formation flying. The record for the largest free-fall formation is held by the 144 American parachutists who, on 11 July 1988, jumped from a height of 4,876 metres and formed a diamond pattern which they held for 8.8 seconds.*

Before the day of the display, the pilot leading the Synchro Pair draws up a map of the site where the team will be performing. His task is to mark out any reference headings the Synchro Pair will use. He also marks the datum — a fixed central point over the spectators, around which the whole display will be orientated. Copies of this map are then sent to the team leader and to two pilots, known as Navigation Officers, whose job is to work out the routes and timings so that the Red Arrows arrive over the crowd at exactly the right moment.

The team leader, whose aircraft is always at the front and centre of the group, calls out brief commands over the radio to synchronize the display. A pattern called Diamond Nine is the basic one from which the Red Arrows develop all of their other formations. All nine aircraft join in formations with names such as Feathered Arrow (familiarly known as 'Fred' by members of the team), Corkscrew, Big-T Leader's Benefit, Swan, Vixen Break, Twizzle, and Parasol Break. At other times the Synchro Pair break away to do their own breath-taking crosses.

Warning sign

With commands like 'Smoke On', 'Pulling Up', and 'Coming Left' the leader warns other team members of the next manoeuvre. He ensures that his own plane is properly orientated with respect to the agreed datum and is moving at the right speed before calling on the rest of the team to fall in behind. Because the physical demands on each plane vary greatly according to the position it flies in, the aircraft are given different numbers each year to make sure they wear at an even rate.

Weather worries

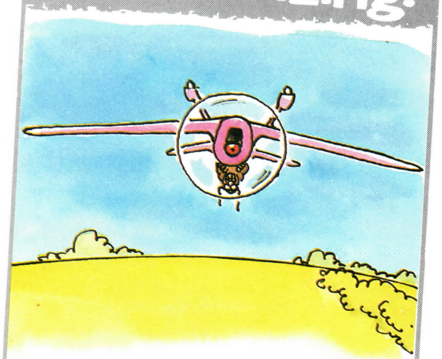
Weather conditions play a crucial part in aerobatics and formation displays. The Red Arrows, for instance, only fly their full programme, including loops and rolls, if the cloud base is no lower than 1,500 metres and visibility is good. If clouds extend down to 800 metres, the team does its spectacular rolls but no high loops. With a cloud base down to 300 metres, the team reverts to its 'flat display', making a series of passes above the crowd.

ONE-MAN JET PACKS

Gamma/Frank Spooner Pictures

The 1984 Los Angeles Olympics opened with a spectacular ceremony that featured a demonstration of the Bell Jet Flying Belt. This is a back-pack powered by a mini jet engine that propels the pilot vertically and horizontally through the air. The jet engine provides a maximum upward thrust of 195 kg. The US Department of Defense and Advanced Research gave the Bell Aerospace Company a $3 million contract to develop the the back-pack.

Just amazing!



MARATHON MAN

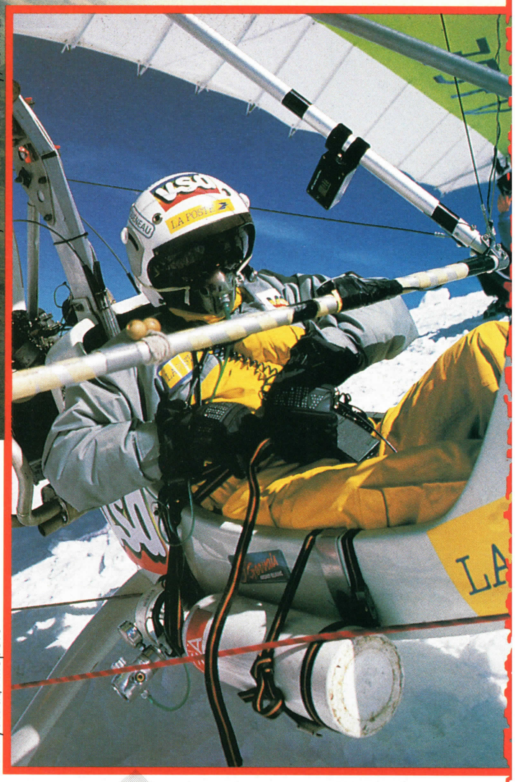
ON 23 AUGUST 1980, AMERICAN PILOT JOHN MC CLAIN FLEW HIS AIRCRAFT OVER HOUSTON, TEXAS, FOR 4 HOURS, 9 MINUTES AND 5 SECONDS – UPSIDE DOWN!

Paul Raymonde

***Microlights** can carry no more than two people. Their weight – excluding fuel or passengers – must not exceed 150 kg.*

Tony Stone Photo Library, London

MICROLIGHTS



Vandystadt/Allsport

***The World altitude record** is held by Australian Eric Winton, who in 1989 flew his microlight to a height of 9,189 metres.*

FOR THOSE WHO CANNOT afford a private jet, microlights offer seat-of-the-pants flying at very low cost. Capable of carrying one or two people, they can be bought ready-made or assembled from kits by any capable mechanic.

Keeping down cost and weight are two key factors in microlight design. Generally, the wing is like that of a hang-glider — a triangular-shaped sheet of nylon stretched across an aluminium frame. Below this the pilot sits in a tiny, open cockpit. Some microlights also have room for a single passenger.

A typical microlight is powered by a two-stroke, 250-350 cc, petrol-driven engine, such as that used in a lawn-mower. The engine may be front- or rear-mounted and is connected to a propeller that drives the craft through the air. A fuel tank with a capacity of about 20 litres provides roughly one hour's flying time, during which the plane may cover 50 km.

Flying for fun

Microlights were developed by hang-gliding enthusiasts, who found the limited availability of sites a major drawback. Hang-gliders can only take off on rising currents of air – usually in hilly areas. This means that pilots often have to travel long distances to find a suitable location. By fitting small engines, a hang-glider could be operated from flat ground.

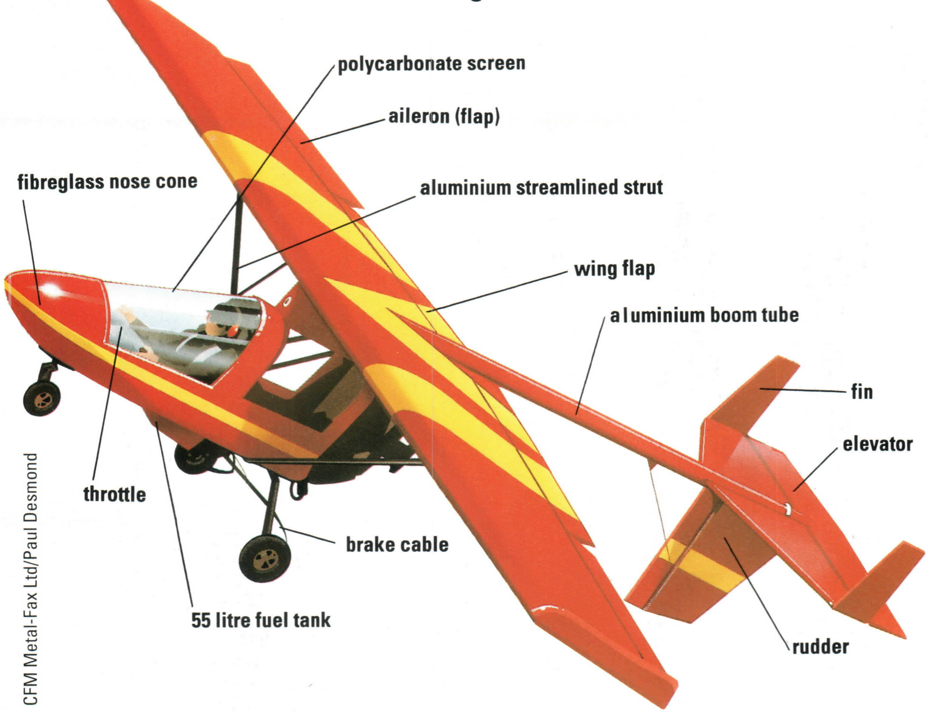
Since most people who fly for fun are not experienced pilots, microlights must be both easy to handle and relatively safe.

The controls are kept as simple as possible, in many cases just consisting of a throttle, a lever connected by cable to the wing, and a bar joined by another cable to the rudder. Pushing the lever backwards or forwards alters the angle of the wing to change altitude, while twisting the rudder bar left or right with the feet steers the microlight.

No escape

Safety is of vital concern in microlights because, in an emergency, the pilot has no way of escape. Although some microlights reach an altitude of 4,000 metres, most only fly at a

A home-built microlight – the 'Streak Shadow'



CFM Metal-Fax Ltd/Paul Desmond

few hundred metres. Attempting a parachute jump from this height would be suicide.

Microlights are designed so that their stalling speed is as low as 30 km per hour. Normal cruising speed is in the range 45-60 km/h with a top speed of up to 80 km/h, though high-powered models may fly at least twice as fast as this. A microlight's take-off run can be less than 50 metres and the climb rate averages 200 metres per minute.

Crash course

Microlight enthusiasts face the same kind of danger as, for instance, ski jumpers do. If something goes wrong while taking off or landing, the microlight pilot stands to collide with the ground with little indeed to protect him.

Most microlights have very good positive stability. This means that they recover quickly from a minor piloting error or light turbulence in the air. They are also highly manoeuvrable and easy to pull out of a stall. Even if the engine cuts out, the pilot can simply glide down to land in the nearest clear area. Consequently,

***The 'Streak Shadow'**, a more sophisticated microlight, can cruise for up to 640km at a speed of 160 km/h.*

microlights have as good a safety record as commercial aircraft.

But accidents do happen. Microlights can be seriously affected by strong winds because they fly at such low altitudes. Using unprepared landing strips can also cause problems. How serious these accidents are depends on the speed of collision and the weight of the aircraft. A crash helmet and safety harness afford some protection to the pilot, while the forward part of the plane is usually designed to absorb at least some of the impact of a crash.

Mini helicopters

Just as the microlight is the ultimate in small planes, so the autogyro is the last word in miniature helicopters. It, too, gets its forward power from a tiny engine and propeller. But in place of a flexible wing it has a rotor blade. This rotor turns in the wind as the craft taxis down the runway, giving lift for take-off.

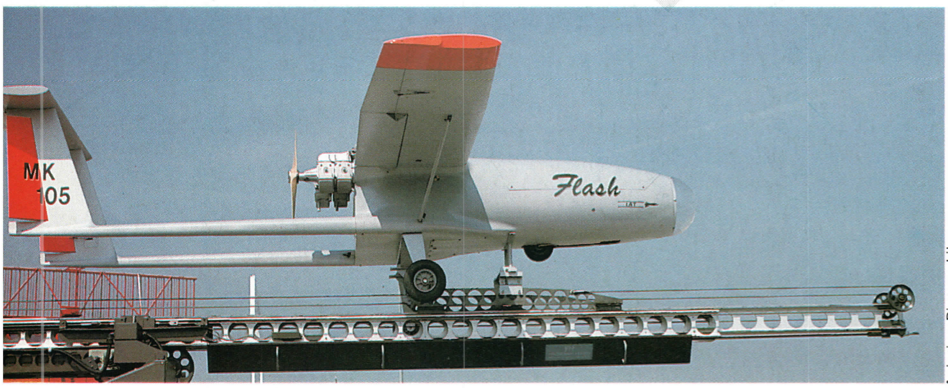
The autogyro's rotor, however, is not powered by the engine. It will only spin and supply lift providing there is sufficient forward motion. As a result, autogyros cannot hover, or land and take off vertically, as conventional helicopters can.

007 AUTOGYRO

This mini-helicopter (below) made a spectacular appearance in the James Bond film, *You Only Live Twice*. It was designed and built by retired Wing-Commander Kenneth Wallis. For the film, the craft was fitted out with model forward-mounted machine guns and twin air-to-surface guided missiles.

In 1975, Wallis set a new straight-line distance record for autogyros by flying 874 km. He went on to break the altitude record with 5,644 metres and in 1986 set a new speed record of 194 km/h.

Mike Valente/Fast Lane



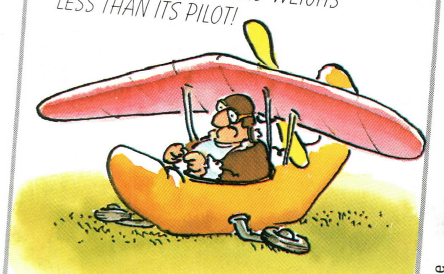
***Remote-controlled** microlights are being adapted for military purposes, such as rescuing pilots from behind enemy lines.*

Aviation Picture Library

Just amazing!

DOT ON THE HORIZON

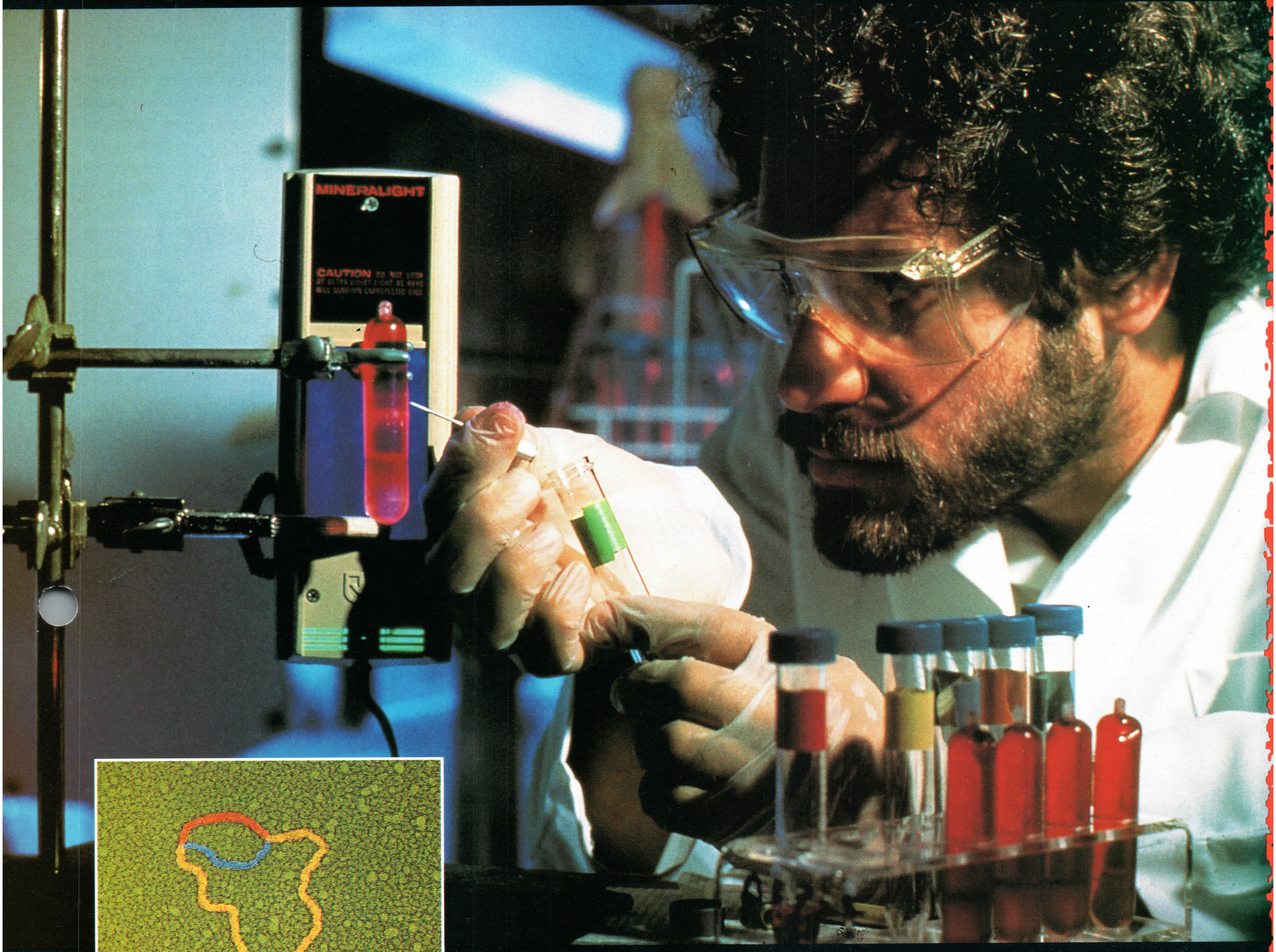
THE SMALLEST TWIN-ENGINED PLANE IN THE WORLD IS THE CRICKET. IT STANDS JUST 1 METRE HIGH AND WEIGHS LESS THAN ITS PILOT!

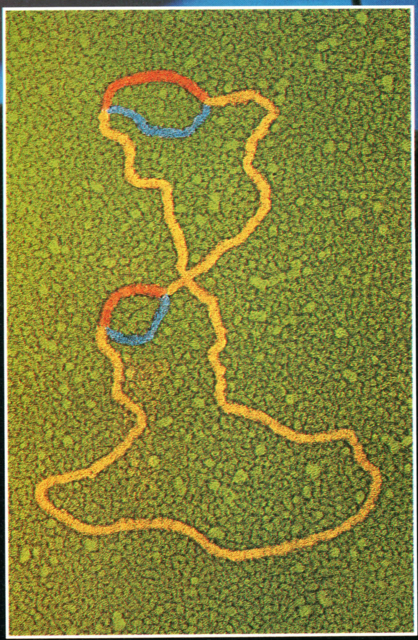


Paul Raymonde

X-RAYS ENDOSCOPY GENE MARKERS

MEDICINE NOW





A McTurk University of Leicester & D Parker/SPL

***Identifying individual genes** on a strand of DNA with coloured dyes in a process known as 'gene mapping' – the first step in finding the cause of disease.*

ADVANCES IN MEDICAL science now enable many childless couples to have families of their own, amputees to have replacement limbs, the deaf to regain their hearing and the blind to have their sight restored.

All of these modern miracles are the result of a mass of painstaking research by anonymous workers. Dr Christian Barnard, for example, would not have been able to perform the first human heart transplant without the 'backroom' scientists developing techniques for accurate tissue typing, engineers improving heart/lung machines, organ storage containers and vital monitors to check the condition of the patient during and after the operation.

***A research scientist,** looking for a cancer cure, uses ultraviolet light while extracting DNA from a solution during a genetic engineering experiment.*

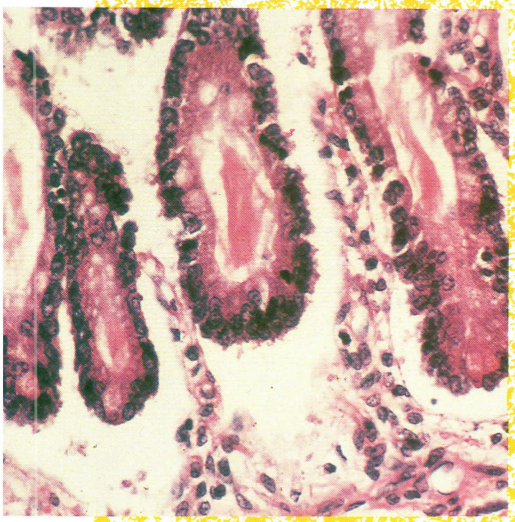
Hank Morgan/Science Photo Library

Many of these advances have happened very slowly as early, simple techniques and machines have been modified and improved over many years. The need for these advances creates its own pressure for improvement.

Fibre optics

The endoscope (from endo, meaning inside and scope, meaning to see) is an instrument that uses the fact that light can be conducted along very thin fibres of glass. Fibre optic bundles are bound together with

THE SEARCH FOR THE CF GENE



Cystic fibrosis is a hereditary disease that affects about one in every 1,000 newborn babies. It results in an abnormally thick mucus secretion in the lungs that leads to severe breathing difficulties, lung infection and death. In spite of treatment, including a special diet, antibiotics and special massage, most sufferers die before the age of 30. In August 1989, however, researchers in Toronto, Canada, and Michigan, USA, pinpointed the gene responsible for the disease. While a 'cure' is still some time off – best estimates are five to ten years – it is now possible to identify carriers with a simple blood spot or mouthwash test. Researchers are already working on drugs that will eliminate the effects of the defective protein within the gene that causes the disease.

Dr Chris Burton/Science Photo Library

the bodies of patients. Sheets of crystals impregnated into plastic film are pressed against the body area under examination and the crystals are warmed — colour changes indicate the degree of warmth.

Colour zones

The crystal sheets are photographed and the colour zones interpreted. This way, tissue damage may be seen directly and, by repeating the procedure over a period of time, the effectiveness of treatment can be fully assessed.

Genetic fingerprinting (see FUTURES, page 22) uses the unique genetic component of people to identify and/or match tissues. Protein from an individual gives a characteristic pattern when separated using electrophoresis. This involves a small amount of tissue fluid being placed in a gel and an electric current applied across the gel for a certain period. The molecular size of the biological material determines the speed that the material moves through the gel. At a given time, the current is switched off and the material in the gel stained. The stripes produced are unique to the tissue tested.

Provided a piece of biological tissue — blood, hair or skin — has been left at the scene of a crime, this method can be used to help catch and convict criminals and, even more important, establish beyond question the innocence of other potential suspects in a case.

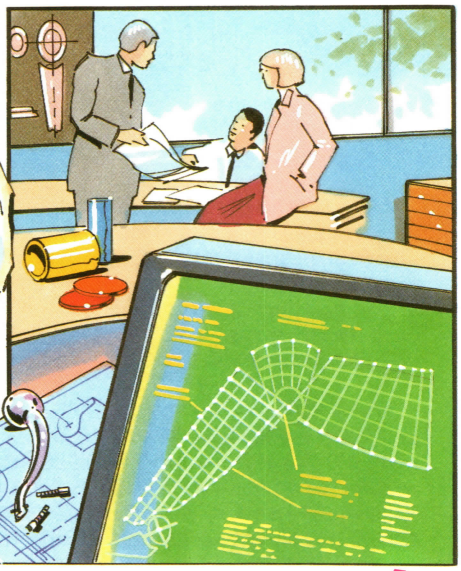
Flexi-Therm Inc

***Thermography** uses heat-sensitive sheets to make a temporary image. A camera produces a record (above) to study disease or injury and subsequent treatment.*

INTO THE FUTURE

BIOLOGICAL ENGINEERING

▲ Biochemical surgery and manipulation will end hereditary disease and will also enable parents to decide the look, hair and eye colouring of their children.



▲ Advances in computer technology and materials will mean that engineers and surgeons will work together to produce functional, lifelike replacement limbs.

▲ Eventually, Man will learn to tap the hidden powers within his own body to induce self-healing and create and maintain a state of permanent health.

Joe Lawrence

GHOSTBUSTING

Mary Evans Picture Library

THE APPEARANCE OF GHOSTS, strange unaccountable noises, inanimate objects flying around, a person that levitates or speaks in strange voices — all are manifestations of the paranormal, phenomena outside the range of normal scientific investigations.

The study of paranormal activity or, to give it its modern name, parapsychology, is perhaps one of the most demanding areas of scientific research. Not only do ghosts and other inexplicable phenomena rarely perform to order, orthodox scientists do not even accept the evidence that paranormal research produces.

The ghost of Raynham Hall, *Norfolk, UK, claimed to be a woman, was captured on film by a Captain Provand in 1936 as it drifted down the staircase.*

A ghostly image *that appeared on a picture of Limassol Bay, Cyprus. The photographer maintains that there was nothing there when he took it.*

George Kanigowski/Fortean Picture Library

Minilab

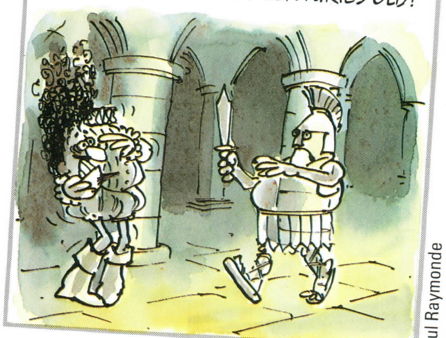
Perhaps the most famous group dedicated to experimentation with the paranormal is SORRAT (the Society for Research into Rapport and Telekinesis) in the USA. When it was formed in 1961, SORRAT was simply a group of researchers into the paranormal that met in order to produce movement of objects and noises through the harnessing of psychokinetic 'energy'. It began to attract great fame and no little notoriety in the mid-1970s, however, with its use of the 'minilab'. Designed by PK specialist William Cox to 'trap' phenomena, this is an upturned aquarium with a sealed bottom, containing objects for the PK energies to play with. A movie camera is set up to record automatically any movement inside.

Since 1977, when the first films were shown, 'Cox's box' has become

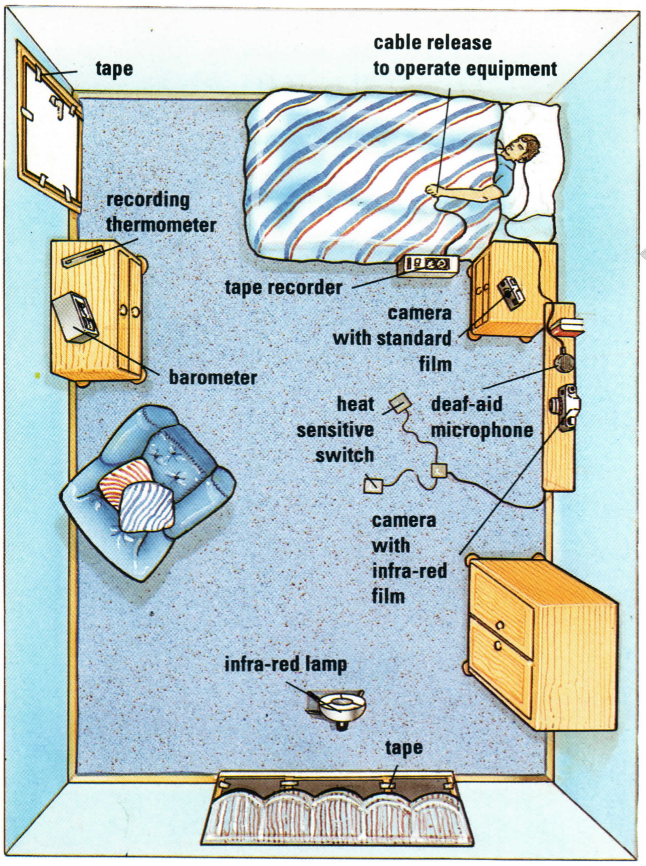
Just amazing!

LONG-LIVED GHOSTS

ALTHOUGH GHOSTS NORMALLY DIE AFTER 400 YEARS, YORK MINSTER, UK, HAS HAD RECENT SIGHTINGS OF THE GHOSTS OF ROMAN SOLDIERS— 19 CENTURIES OLD!



Paul Raymonde



John Houghton

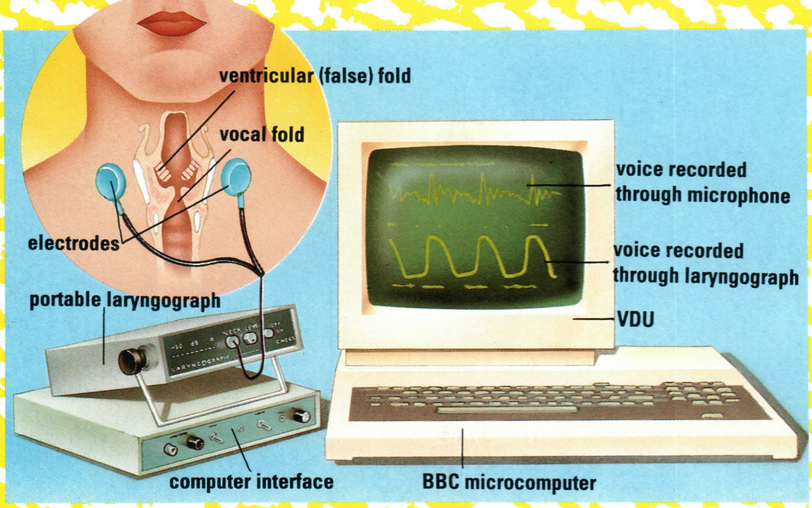
A parapsychologist *will seal off a room in which strange events have been reported and attempt to detect and record any paranormal phenomena with a host of equipment. A length of thread is run around the room and arranged to trigger a camera loaded with infra-red film if anything brushes against it.*

GHOSTSPEAK

ESP (Extra Sensory Perception): an extra sense, such as telepathy, outside the five known human senses
poltergeist: a 'noisy ghost'
psi: the umbrella name given to all psychic abilities and phenomena
psychic: force that has no physical explanation
psychokinesis (PK): the ability to move or change objects with the mind
telepathy: the ability to communicate thoughts over any distance


Graham Morris

LOOKING AT STRANGE VOICES

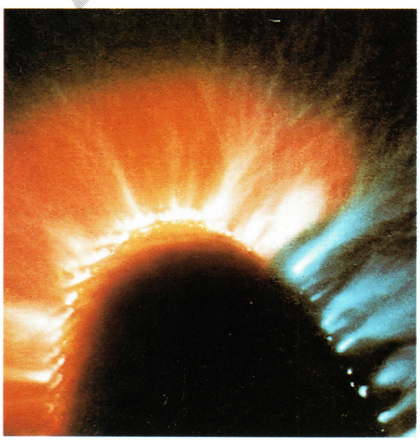


Among the many phenomena occurring in the Enfield poltergeist case was the voice of an old man that came from Janet, the young girl at the centre of the paranormal activities. Psychic researchers used a laryngograph to test whether Janet was simply reproducing the voice herself. This device monitors the action of the larynx by passing a high frequency signal between two electrodes positioned either side of the throat. It was found that the voice came not from the larynx, but from the ventricular or 'false' vocal fold. Normally, it is impossible to produce sounds from here for more than a few minutes without damaging the throat. Yet Janet's 'voice' continued conversation for hours without any apparent discomfort to her.

Mark Franklin

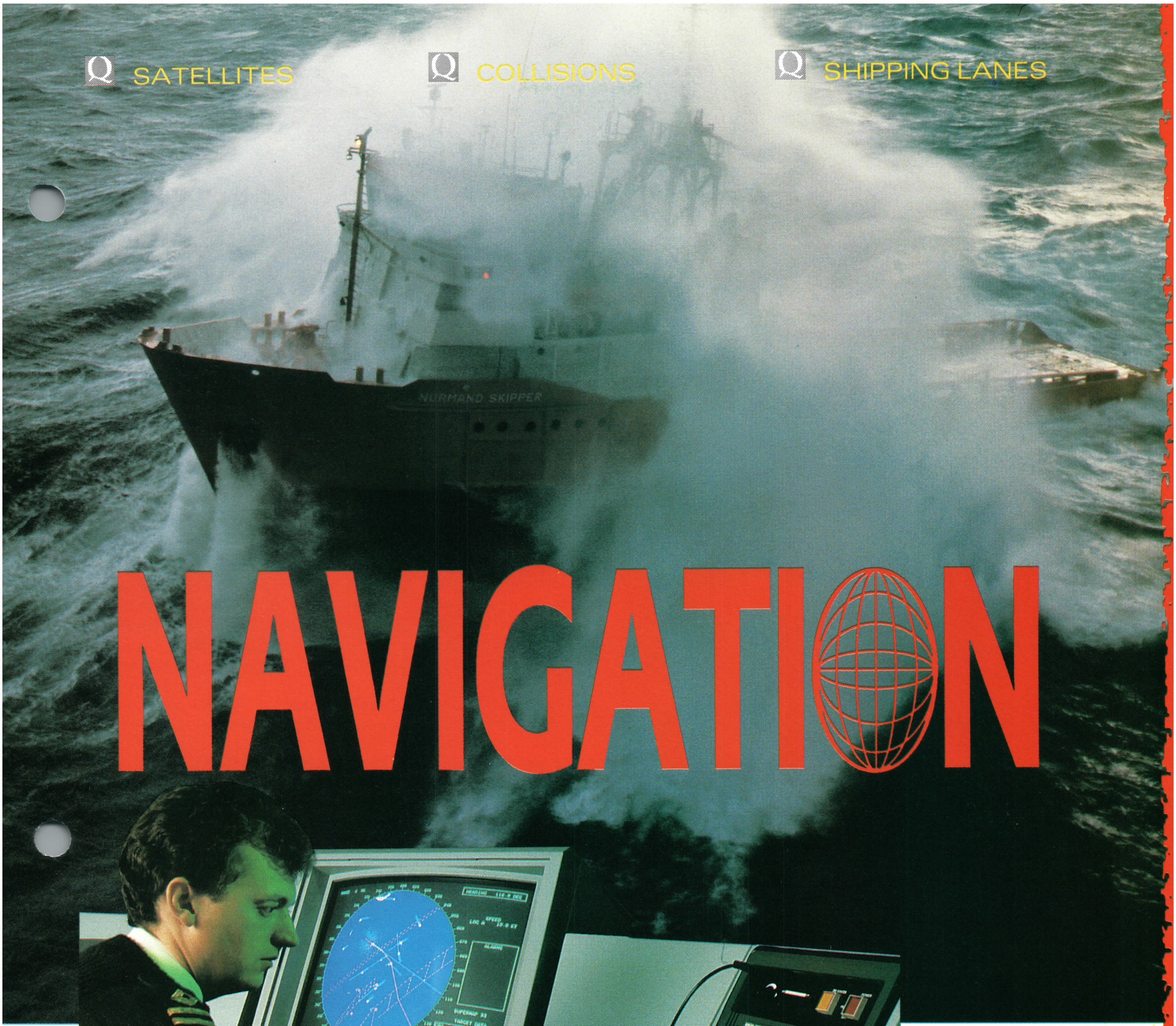
Kirlian photographs *are produced by passing the subject between two metal plates, on one of which is a sheet of photographic film, while a current is run from one to the other. The 'auras', shown here around a fingertip, may be evidence of an electrical 'life' field within all creatures.*

Poltergeist activity *was well documented in a case that occurred in Enfield, North London, UK, in 1977-78. Janet, the girl at the centre of the activity, was captured by* Daily Mirror *photographer, Graham Morris, apparently flying around a bedroom.*


Novosti/Science Photo Library

the source of heated controversy. The films show such phenomena as packs of cards sorting themselves into suits, pens writing by themselves, spontaneous combustion of objects and rubber rings linking and unlinking, then jumping *through* the glass wall of the minilab.

Whenever paranormal activity is discovered and verified 'in the field', investigators try and reproduce the effects in a laboratory. In Enfield, North London, UK between 1977 and 1978, there occurred a series of paranormal events manifesting from a young girl that resulted in one of the best documented cases this century. Members of the Society for Physical Research recorded examples of levitation, the strange voice with which the girl spoke and other strange noises. Then she underwent tests at London University, UK, to see whether she could levitate or show abnormal powers under controlled conditions. At first nothing happened, then suddenly two weight increases of about 1 kg, each lasting about 5 seconds, were recorded. No explanation could be found.



NAVIGATION

Racal Marine Electronics Ltd

***The* Normand Skipper** *ploughs through the North Sea, taking supplies to an oil rig. To find the way, every ship must have navigation equipment on board. Many use Racal-Decca integrated systems (left), which include radar displays, a navigation processor that calculates the ship's position at any given moment and a colour video plotter.*

Tony Stone Photo Library, London

WHEN THE FIRST SAILORS set sail, they steered by the stars. Modern mariners are also guided by the heavens - but it is satellites that show them where they are and, instead of looking up at the skies, they look down at a computer screen.

That is essentially what the modern navigator has to do: look. On the bridge of a modern ship, the sophisticated modern navigation system is connected to the autopilot. Once details of the voyage have been programmed in, the ship steers itself .

Navigation literally means 'ship-driving'. A navigation system must get the ship to its destination on time and without accident. As sea routes become more and more busy, collision avoidance is growing in importance. Ships may be large and easily seen, but they are also hard to manoeuvre, slow-moving and require a long time to stop.

One of the main satellite navigation

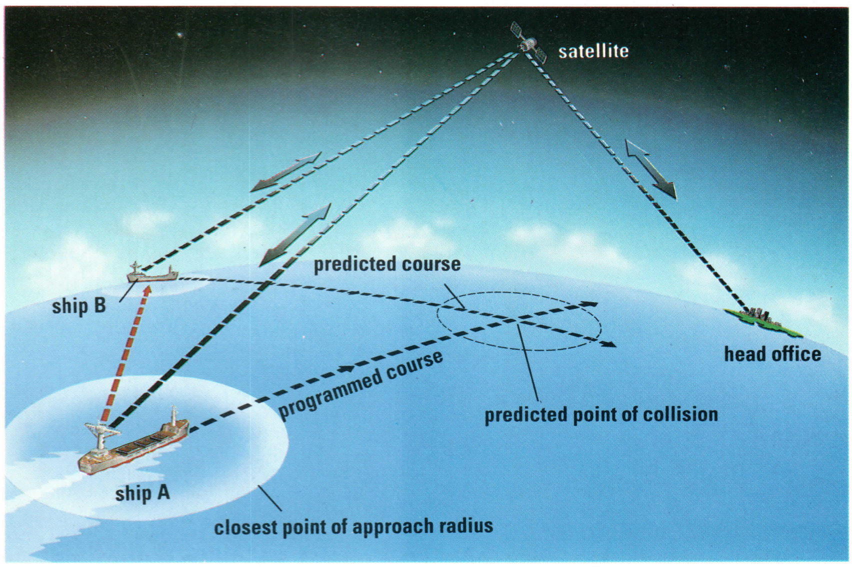
systems is the US Air Force's NavStar Global Positioning System (GPS). Eighteen satellites orbit the Earth at an angle of 63° to the Equator and the signals they transmit scan the surface of the Earth.

Each satellite sends out a signal on a precise schedule timed by an atomic clock. On board ship, a receiver automatically selects signals from the three or four nearest satellites and feeds them into a computer.

Position fixing

The computer works out the time delay between when each signal was sent and when it was received. This gives the ship's distance from each of the satellites. From these figures the computer can work out exactly where the ship is.

Kim Taylor/Bruce Coleman Ltd



***In the future**, merchant ships could be unmanned – sailed by computers. Radar, computer and satellite systems will combine to avoid collisions. Ship A's radar would forecast that ship B will come dangerously close. This would trigger contact with ship B and head office, so the ships' courses could be altered.*

***Portland Bill** lighthouse on the south coast of England. Its electric light burns with a 3,370,000 candle-power intensity, seen from 47 km out to sea.*

***St Mathieu lighthouse** in Britanny, France. Each main lens is surrounded by glass rings that refract the central light, producing a beam with a range of 45 km.*

Gamma/Frank Spooner Pictures

Precise details of any variation in the orbit of the satellite and the time intervals between transmissions are broadcast with the signal in a data stream. This means the on-board computer can make any adjustments necessary to make the position fix as accurate as possible.

Global coverage

GPS actually provides two services. The Precise Positioning Service is very accurate and reserved for use by the military, and the other is the Standard Positioning Service, which is available to other users. This can fix a vessel's position anywhere in the world to within 10 metres. In addition, the USSR has its Global Navigation Satellite System (Glonass) which uses 12 satellites to give global coverage.

Distress system

The Russian and the American systems have been integrated into a single global distress system by Inmarsat (International Maritime Satellite Organization) that includes other satellites sent up by Inmarsat. The system monitors the airwaves around the clock for automatic distress signals. Equipment on board automatically uses the satellite communication system to broadcast the name of a ship when it is in distress, also using the satellites to establish the ship's precise position.

Search and rescue

The system is known as COSPAS-SARSAT – SARSAT stands for Search and Rescue Satellite Aided Tracking System (COSPAS is the Russian equivalent). It is also used to direct search and rescue services and salvage ships to any vessel in distress. In its first five years of operation it saved over 1,000 lives.

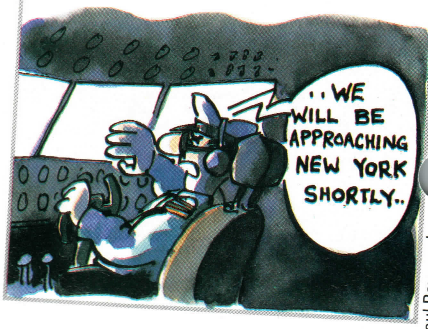
Mayday

If a ship is sinking, and its on-board transmitter no longer works, an Emergency Position-Indicating Radio Beacon,takes over. This is a transmitter weighing 50 kg that

Just amazing!

LIGHT FANTASTIC

EACH NAVIGATION LIGHT ON THE EMPIRE STATE BUILDING IN NEW YORK SHINES WITH THE INTENSITY OF 450 MILLION CANDLES AND CAN BE SEEN FROM AS FAR AWAY AS 490 KM.



Paul Raymonde

***A lightship** warns other ships of dangerous waters. It is moored above sandbanks and shoals, where a lighthouse cannot be built.*

Geoff Harwood/Planet Earth P…es

automatically sends out a distress signal when it is immersed in seawater.

Plotting a course

Inmarsat began operations in 1982. For the first time shipping had a communications system reserved solely for its own use and designed for its own purposes.

Inmarsat is funded by member countries, and runs coastal stations, (as do most maritime nations). Signals sent out by these stations are picked up by a receiver on board ship and fed into a computer to give an accurate fix when the ship is nearing land.

When planning a voyage, the navigator fixes several 'waypoints', by feeding the longitude and latitude of points that the ship should pass during the voyage into the navigation computer. At any time during the voyage, the computer will display the ship's position, the proposed course and any deviation from it that may have been caused by tides, currents or gale force winds.

The automatic pilot will make any necessary adjustments and work out when to begin the turn to make a 'smooth steer' between one leg of the voyage and the next. Naturally, course alterations can be made during the voyage by moving waypoints or entering more into the computer.

One-way traffic

Details of the course are stored on floppy disks so that they can be easily be transferred from one ship to another. Video maps of estuaries and harbour facilities are also available on disk so that when a ship reaches its destination port the same system can be used to steer it safely into its berth.

Modern lighthouses, lightships and danger-marking buoys broadcast radio and radar warning signals that are fed into the system. Lightships and large warning buoys are also used to mark out one-way traffic lanes in busy waters

In the English Channel, for example, east-bound shipping must stick to a southern lane, nearer the French coast. West-bound shipping must stick to a northern lane nearer

COLLISION AT SEA

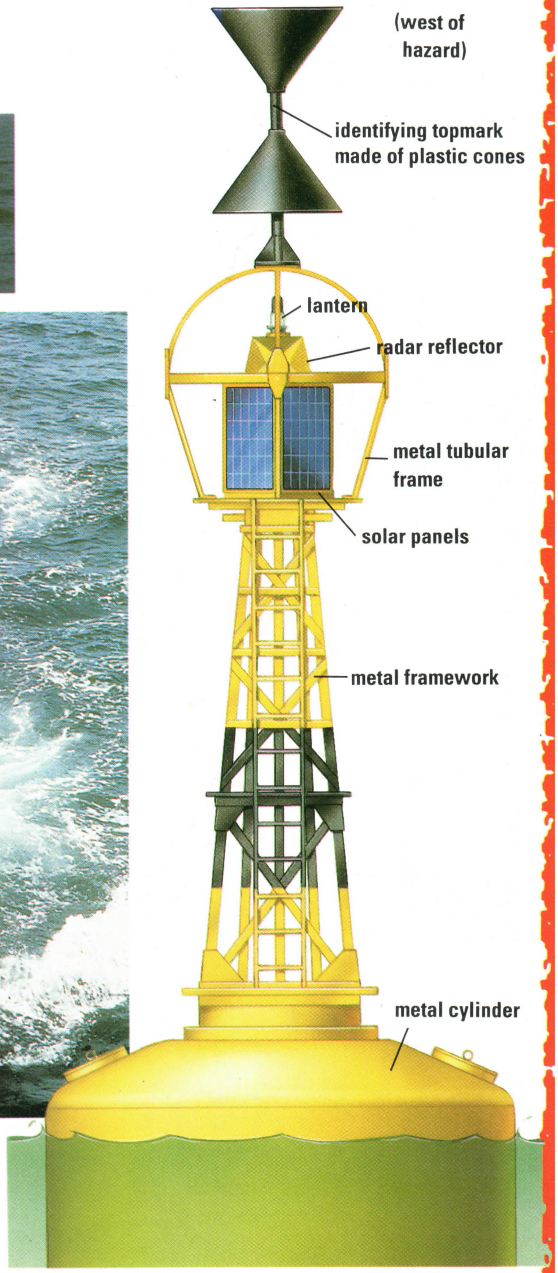
Despite all the modern equipment available, ships still run into each other. These collisions usually occur because of human error, in crowded waters, in heavy seas and often when visibility is poor. But visibility was moderate to good in the Humber Estuary on the north-east coast of England early on 19 September 1989, when two oil tankers collided – the *Philips Oklahoma* running into the *Fiona*. Although more than 40,000 ships pass through the estuary every year, the nearest coastguard station was some 64 kilometres away and did not have the radar equipment necessary to warn of the impending collision. The impact tore a seven-metre-long gash in the *Philips Oklahoma*, spilling more than 200 tonnes of oil into the North Sea. Fire forced 16 Filipino crewmen on the *Philips Oklahoma* to abandon ship.

Ambrose Greenway

***Lighted buoys** warn ships of shallow water and mark sea lane boundaries. Gas-powered buoys must have their gas cylinders regularly refilled.*

***Solar-powered buoys** are replacing other lighted buoys, because they do not need to be refuelled. Trinity House (the General Lighthouse Authority for England, Wales, the Channel Islands and Gibraltar) paints buoys in different combinations of yellow and black to show whether the buoy is north, south, east or west of the hazard or shipping lane that it marks.*

Cardinal Class I Buoy



Paul Williams

the English coast. Between them there is a separation zone and there are also inshore zones solely reserved for inshore traffic.

Yachts and cross-Channel ferries still cause problems, dashing across the sea lanes like pedestrians on a motorway. But on modern cargo ships plying up and down the Channel, the whole traffic system can be displayed at the press of a button.

Radar is also used to avoid collisions and sonar devices to warn the ship's officers of shallow water.

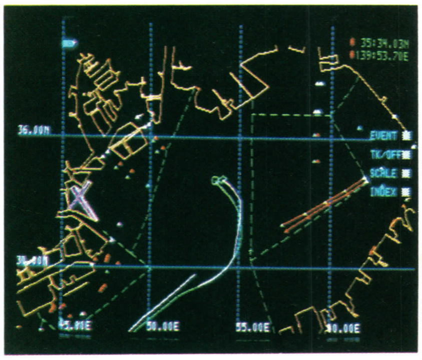
The navigation equipment on most ships is integrated into the communications system as a whole. The development of maritime satellite communications is having an impact as great as the invention of the wireless telegraph around the beginning of the 20th century.

Spreading the news

Many modern ships have ship-to-shore telephones, connected via satellite to the land. Equipment automatically scans the distress frequencies. Large ships have telex and fax facilities. Some have computer data links with their head office and on-board TV that gives up-to-the-minute maritime information.

ZEFA

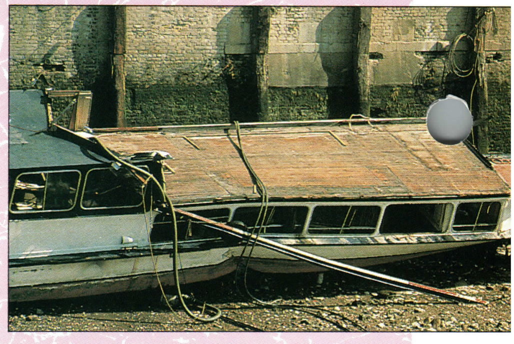
The Panama Canal, *connecting the Atlantic and Pacific oceans through the Isthmus of Panama, is one of the most important artificial waterways in the world. Up to 70 ocean-going ships pass through the canal each day. To avoid collisions, shipping observes a strict system of traffic lanes.*



Racal Marine Electronics Ltd

Colour Video Plotter (CVP) map *of Tokyo Bay. A detailed map of a harbour can be plotted on board an approaching ship by entering into a CVP the longitudes and latitudes of points along the route.*

THAMES DISASTER

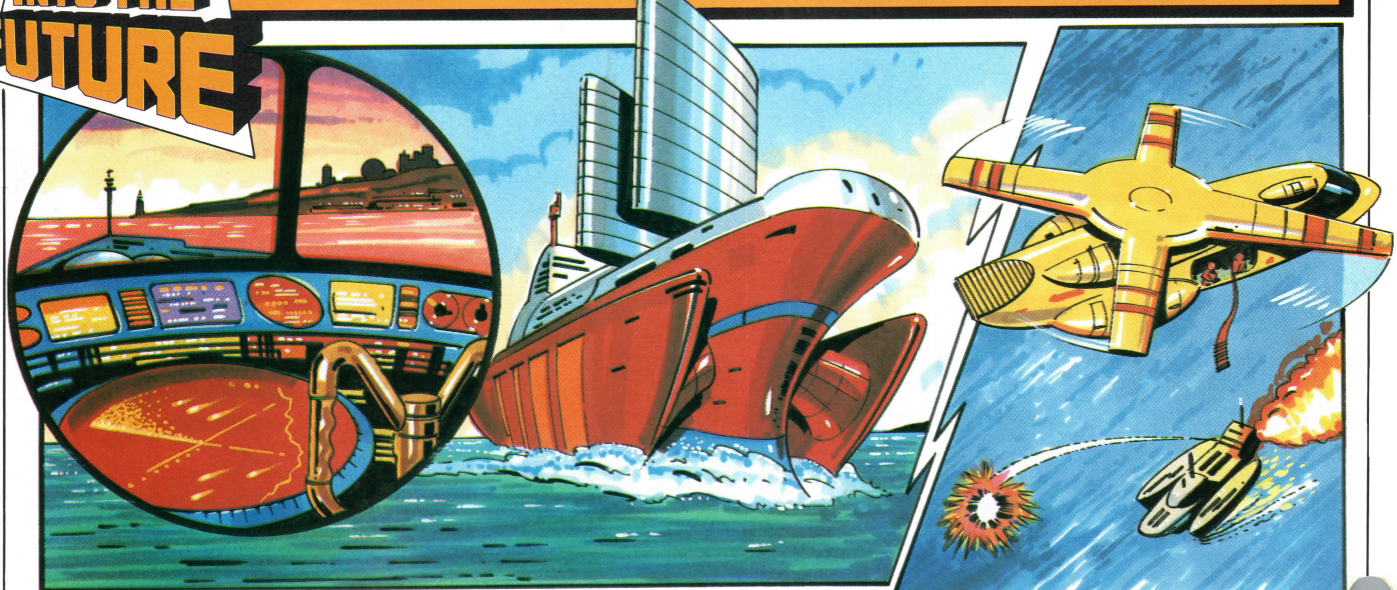


Gamma/Frank Spooner Pictures

The *Marchioness* pleasure boat was almost through the central arch of Southwark Bridge, spanning the River Thames in London, when the *Bowbelle*, a sand dredger four times its size, came up from behind at speed. The dredger smashed into the stern of the smaller boat, forcing it to slew round. The *Bowbelle* then drove into the side of the *Marchioness* and within two minutes the pleasure cruiser had sunk. Fifty-five passengers, most of them guests at an all-night party, drowned. The accident happened early in the morning on 20th August 1989. The boats were attempting to pass through the central arch of Southwark Bridge at the same time, each unaware of the other's position. Only commercial boats such as the *Bowbelle* have to keep the Port of London Authority informed of their movements by radio. Pleasure boats must have a radio on board so that they can monitor shipping movements, but in this case the system did not work. As a result of this tragedy control over traffic on the Thames has been tightened.

INTO THE FUTURE

GHOST SHIPS OF TOMORROW



Joe Lawrence

▲ *Computerized ship-board navigation and cargo handling systems may reach such a point that a crew is no longer necessary on board a cargo ship.*

▲ *A ship could sail on the open sea and in and out of port without a human hand touching the controls – the oceans could be host to a fleet of 'ghost ships'.*

▲ *A crew would be put on to a ship by helicopter for particularly tricky manoeuvres, or when emergency systems put out a distress signal.*

OIL SHIPS

Shell

Oil tankers are the largest and heaviest vessels on the oceans. Once they get up to full speed, they take many kilometres to stop or change course, even at speeds as low as 25 km/h.

Tony Stone Photo Library, London

HUGE SUPERTANKERS CROSS the oceans of the world carrying a total of over 60 million 'barrels' of oil every day — a 'barrel' being 42 US gallons of oil. These half-million tonne monsters can be up to a third of a kilometre long and each one may carry nearly two million barrels of oil.

Tankers are now as large as current designs allow. Should a tanker gets to be as long as the distance between the peaks of two Atlantic storm roller waves, it could find its bow and stern on the peaks of the waves, while its middle section would be clear of the water in the trough. This would probably cause the ship to break in two.

Articulated hulls

In the deep ocean, storm rollers have waves around 400 metres apart. Current supertankers tend to be around 300 metres long. To make tankers longer, it has been proposed that they have articulated hulls. This means that sections of the ship would be held together by huge hinges at deck level which would allow the ship to bend round the shape of the wave trough.

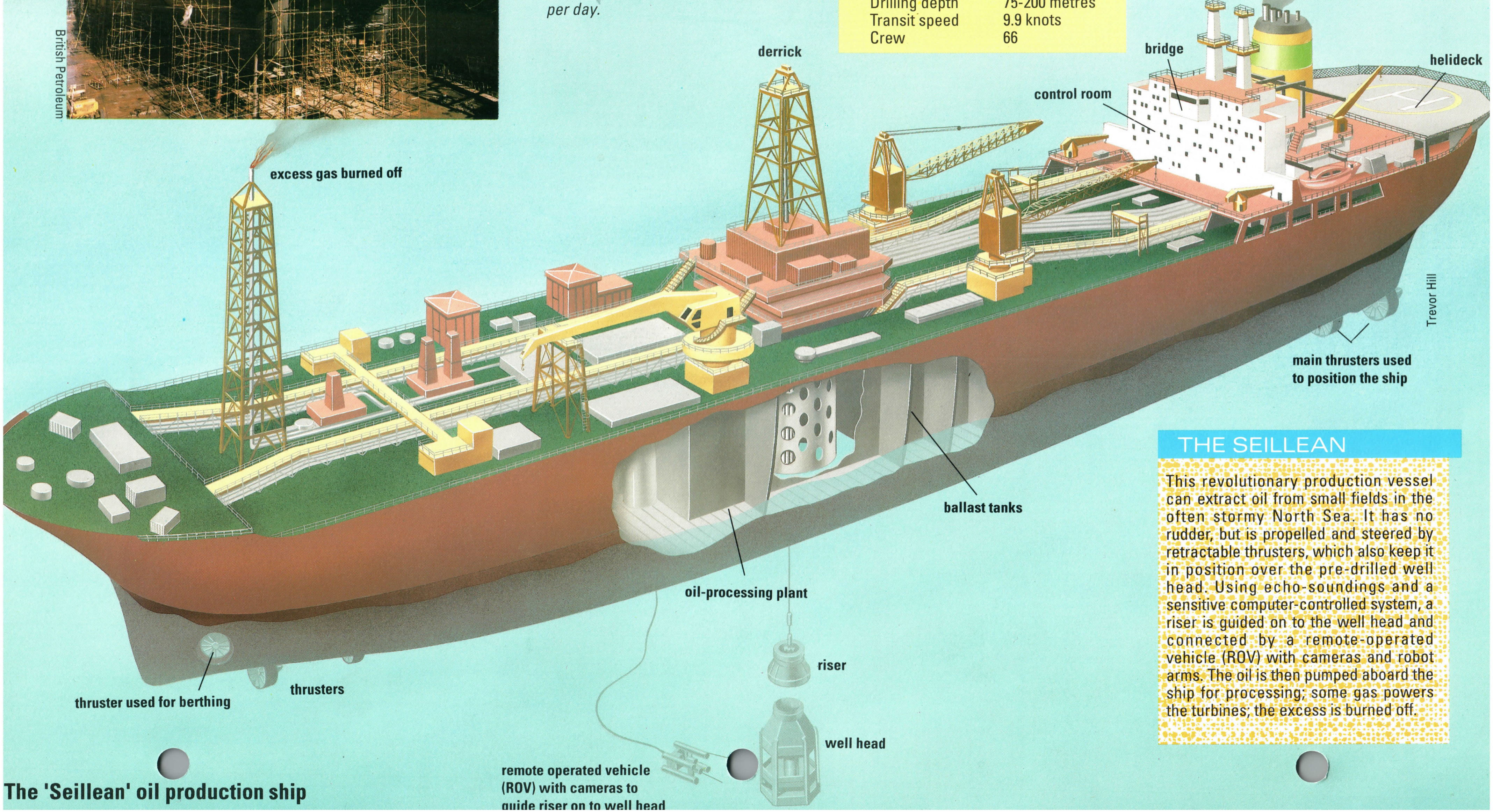
Although huge tankers are vital

British Petroleum

The **Seillean**
(Gaelic for bee) was designed to mop up small pockets of oil beneath the North Sea without the aid of divers. It can handle up to 16,000 barrels of oil per day.

PROFILE THE SHIP

Length	249.7 metres
Breadth	37 metres
Draught	11 metres
Displacement	76,440 tonnes
Drilling depth	75-200 metres
Transit speed	9.9 knots
Crew	66



Trevor Hill

THE SEILLEAN

This revolutionary production vessel can extract oil from small fields in the often stormy North Sea. It has no rudder, but is propelled and steered by retractable thrusters, which also keep it in position over the pre-drilled well head. Using echo-soundings and a sensitive computer-controlled system, a riser is guided on to the well head and connected by a remote-operated vehicle (ROV) with cameras and robot arms. The oil is then pumped aboard the ship for processing; some gas powers the turbines; the excess is burned off.

The 'Seillean' oil production ship

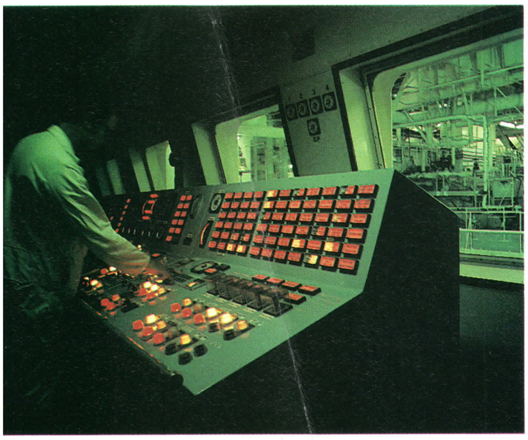
ZEFA

__Supertankers__ cannot get into ports such as Valdez (above), so they must load and unload at sea, by mooring to a large buoy with a pipeline attached.

Shell

for carrying oil around the world, they also carry great risks to the environment from pollution, either through the accidental or deliberate discharge of oil. But it should be remembered that the 390,000 tonnes of oil that enters the sea each year is only about 0.01 per cent of all the oil carried on the high seas.

The most spectacular type of spillage is when one tanker collides with another, or is grounded, like the *Exxon Valdez* off the coast of Alaska in 1989. Even the empty tanks carry enough oil residue to pollute beaches and damage and kill wildlife.



Richard Cooke

__Computerized control rooms__ have enabled shipping companies drastically to reduce crew numbers. As few as 15 men may now crew a giant tanker.

One proposed solution is the double hull. American authorities may soon insist that all oil tankers using their ports must have two hulls — one containing the oil, and a second hull outside to protect the inner hull in the event of a collision.

However, some oil companies claim that a double-hulled tanker could be more dangerous . With a single-hulled tanker, a hole leaks a small amount of oil, but when the pressure of the remainder equals that of the water, the leak stops.

With a double-hulled vessel, however, a hole would leak water into the space between the two hulls, increasing the risk of the tanker sinking. Oil companies also claim that double hulling tankers will make them more expensive — and the extra cost will push up the price of petrol, the main end-product of the oil industry.

New regulations

Although tanker collisions tend to grab the headlines, they account for only 10 per cent of oil spills at sea.

Another source of pollution used to be the deliberate emptying of ballast tanks at sea. An empty tanker must have several of its oil-carrying compartments filled with sea water ballast to weigh it down, otherwise the propeller and rudder would be clear of the water. But when the sea-water was discharged from them, it flushed oil residue out into the ocean.

New regulations say that ballast tanks cannot be used to carry oil when the tanker is full. These ballast tanks, which now have to remain empty when the tanker is loaded, have to be situated at the bow and the sides of the ship, thus acting like a double hull.

Around the world there are a number of superports such as Milford Haven in Wales, Rotterdam in the Netherlands and the offshore oil facility off Louisiana in the Gulf of Mexico, which can handle the Very Large Crude Carriers (VLCC) or the Ultra Large Crude Carriers (ULCC).

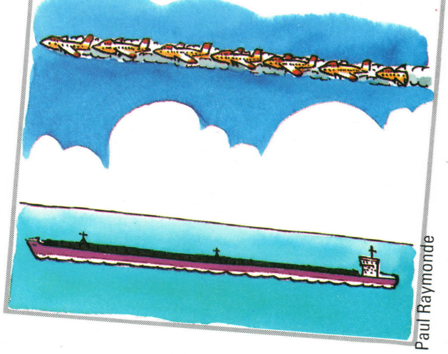
Loading at sea

But most ports cannot handle supertankers. Instead, these ships have to moor to a buoy and load or unload out at sea. To make this safer, a new plug-in loading system is being developed. A huge, self-sealing socket, known as a pipeline end manifold (PLEM), is fixed to the end of the pipeline on the sea bed. The tanker then carries a plug called a remote operated vehicle (ROV) on a long loading hose. When the tanker is in position above the PLEM, the plug is manoeuvred into position by water-jet thrusters. The ROV is positioned using a sound echoing system; once coupling is completed, the loading or unloading can begin.

Just amazing!

SUPERSHIP

THE WORLD'S LONGEST OIL TANKER, THE HAPPY GIANT, FORMERLY SEAWISE GIANT, IS 566 METRES LONG — THE LENGTH OF 7.5 JUMBO JETS!



Paul Raymonde

A container ship *passing through the Suez Canal. The canal links the Mediterranean Sea with the Indian Ocean, thus saving ships a long and hazardous journey around the coast of Africa.*

Hutchison Library

The dhow *was used for centuries by Arabs to transport slaves and goods. Dhows still sail the old Arabic trade routes off the east coast of Africa and the Persian Gulf.*

A passenger ferry *crossing the river Mekong in China. This twice-daily ferry is packed with goods, passengers and even livestock.*

Hugh Jones/Planet Earth Pictures

The Eternal Ace *is one of the world's largest car carriers. Developed by a Japanese company to transport cars from continent to continent., it carries 6,500 cars at a time. The same company's 66 vessels can transport a total of 220,000 vehicles.*

Jeremy Horner/Hutchison Library

Mitsui OSK Lines

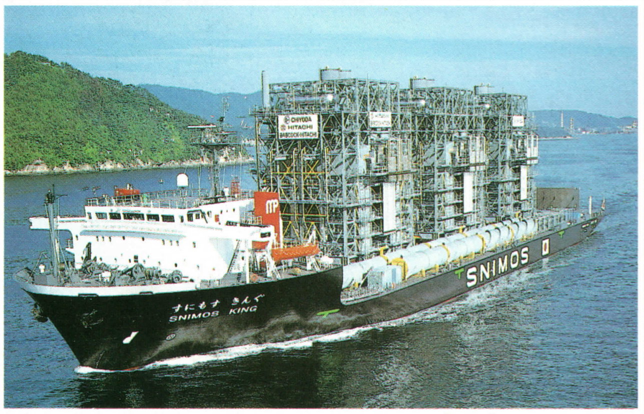
RI Lloyd/Hutchison Library

Highly volatile *liquefied natural gas (LNG) must be carried at -162° C. The crew are specially trained to operate these carriers at an LNG simulation centre in Japan.*

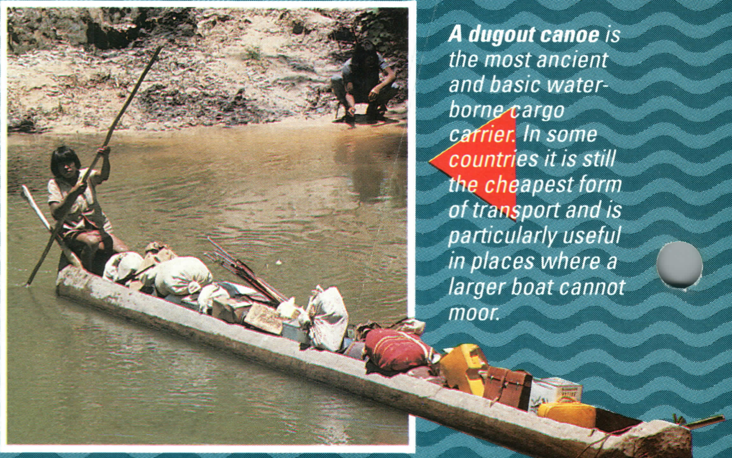
Mitsui OSK Lines

Traditional junks *are still part of the Hong Kong skyline, but are now mostly decorative. They are a large version of the tiny Chinese sampan (which literally means 'three planks').*

This module carrier *can transport a whole chemical plant or similar structure around the world. The complete aft section of the ship is submersible to help unloading.*



Mitsui OSK Lines

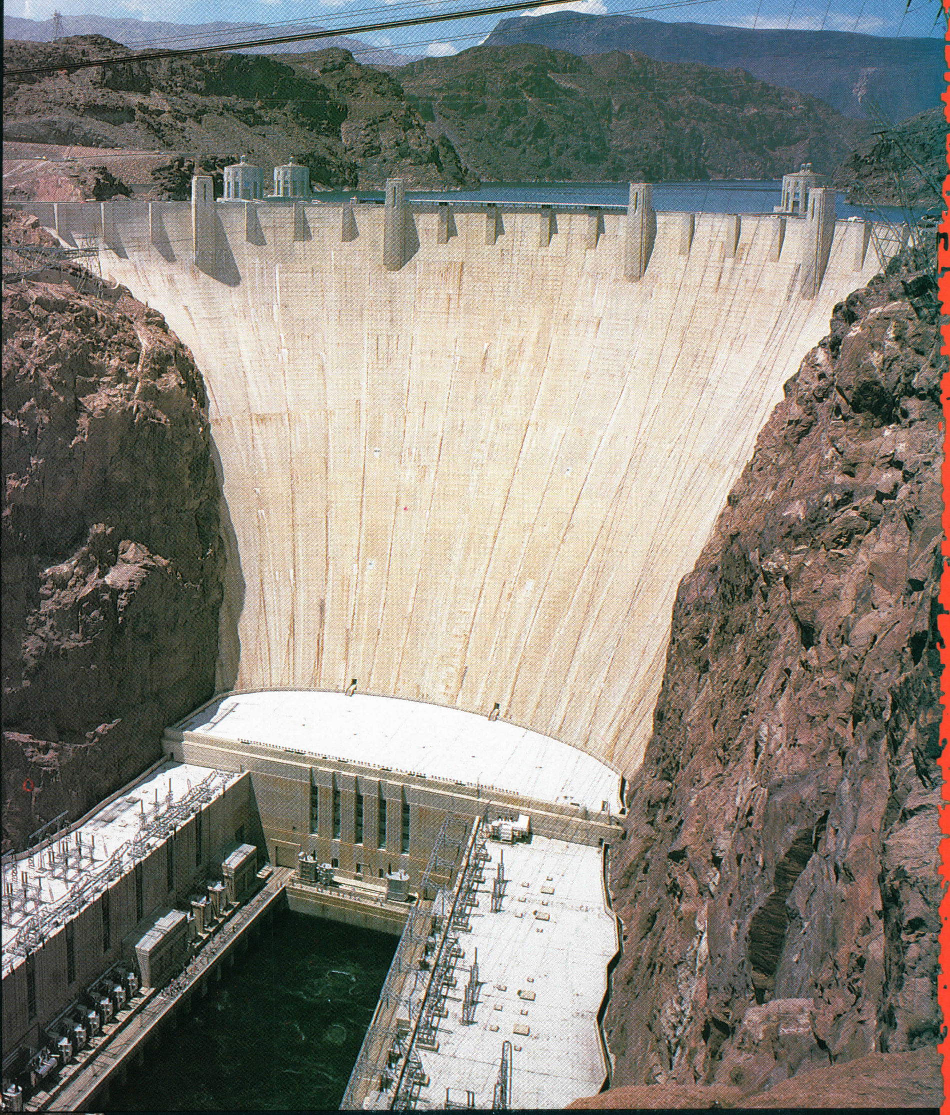


WY Puttkamer/Hutchison Library

A dugout canoe *is the most ancient and basic water-borne cargo carrier. In some countries it is still the cheapest form of transport and is particularly useful in places where a larger boat cannot moor.*

HYDROELECTRICITY IRRIGATION TIDAL BARRIERS

DAM-BUILDING



TAMING AND HARNESSING the power of mighty rivers, dams are among the biggest engineering projects in the world. Dams are designed to supply water for drinking and irrigation, to enable electricity to be generated by hydroelectric power and to stop flooding.

The objective of dam-building is to stem the normal flow of a river and cause its waters to accumulate as an artificial lake or reservoir. During summer, when the river would normally be low, the reservoir will continue to supply water. In winter, the reservoir may become so full that excess water has to be let out through special gates called spillways.

Drawing off water

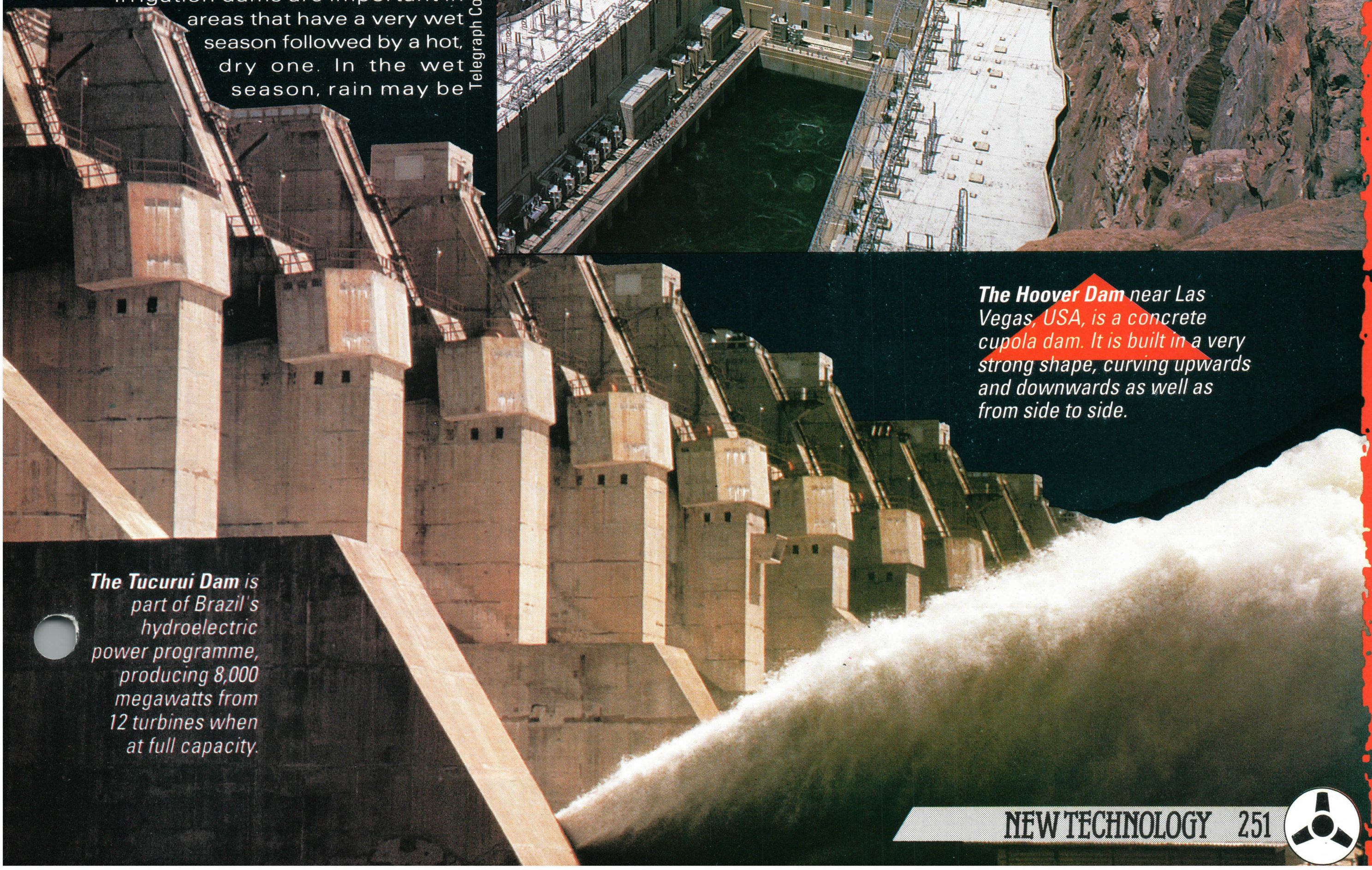
In western Europe, many dams serve simply to hold back reservoirs of water for domestic and industrial consumption. The water leaves the reservoir by submerged pipes, is chemically treated to make it safe for drinking, and then enters the water-distribution network.

Irrigation dams are important in areas that have a very wet season followed by a hot, dry one. In the wet season, rain may be

Gamma/Frank ner Pictures

Telegraph Colour Library

The Hoover Dam *near Las Vegas, USA, is a concrete cupola dam. It is built in a very strong shape, curving upwards and downwards as well as from side to side.*



The Tucurui Dam *is part of Brazil's hydroelectric power programme, producing 8,000 megawatts from 12 turbines when at full capacity.*

George Wimpey plc

torrential, swelling rivers and causing them to flood – with catastrophic results for people and livestock in the surrounding countryside. By contrast, the rivers may stop flowing altogether in the dry season, leaving the land parched. An irrigation dam stores water in the rainy season so that it can then be distributed evenly to communities throughout the year. The Tarbela Dam in Pakistan, does just this. One of the world's largest, it stands 150 metres high, extends for 2.7 km, and holds back a reservoir containing 190 million cubic metres of water.

DAMS THAT BROKE

Few disasters strike more suddenly and powerfully than when a major dam gives way. The worst recent accident of this kind was the collapse of the Manchhu River Dam in Gujarat, India, on 11 August 1979, when around 5,000 lives were lost. In 1963, a huge landslide into the reservoir behind the Vaiont Dam in Italy caused water to surge up to a height of 200 metres above the dam wall. The water poured down on to the town, killing 2,000.

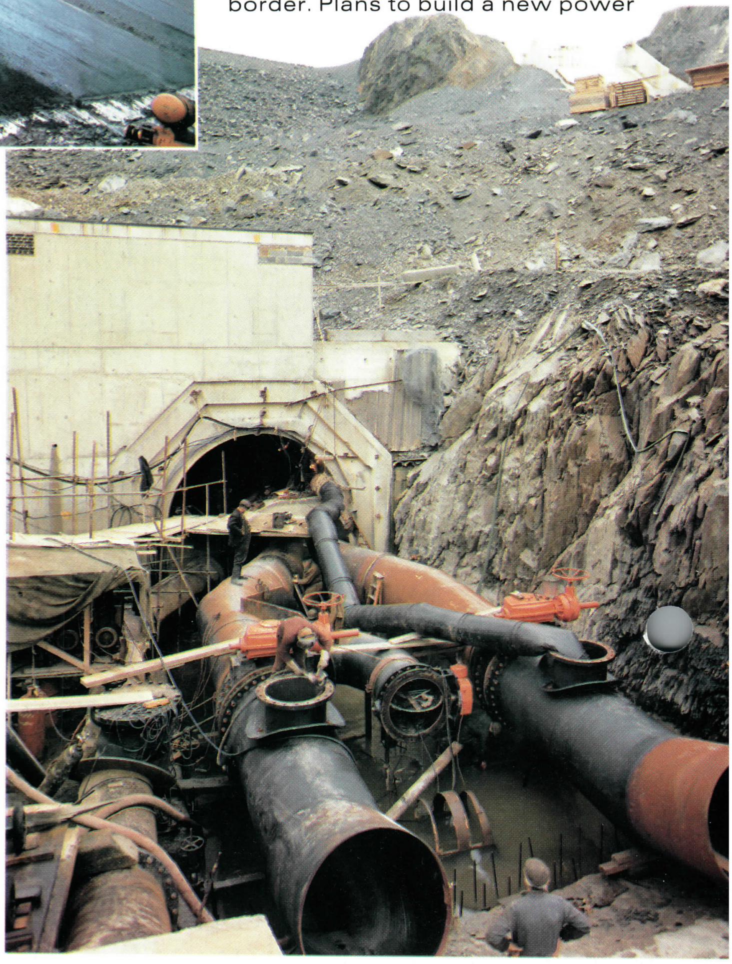
Llyn-Brianne Dam *in South Wales. Normal draw-off of water from the reservoir, which can hold up to 61,000 million litres, is through two steel outlet pipes. At Marchlyn Dam (above), the dam was covered with a thin layer of waterproof asphalt and concrete mix.*

A dam is built *behind a temporary structure called a cofferdam. River water held back by the cofferdam is diverted around the site by specially constructed tunnels. The coffer-dam is eventually incorporated into the permanent barrier.*

Of the many dams that have been built to produce hydroelectric power, the 167-metre-high Grand Coulee Dam on the Columbia River in Washington State, USA, is among the most famous. Completed as long ago as 1942, it has a generating capacity of 6,500 megawatts.

Power to the people

It has now been far surpassed, however, by the 12,600-megawatt Itaipu Dam on the Brazil-Paraguay border. Plans to build a new power station on the Tunguska River in the USSR capable of producing a staggering 20,000 megawatts of electricity were announced in 1982.



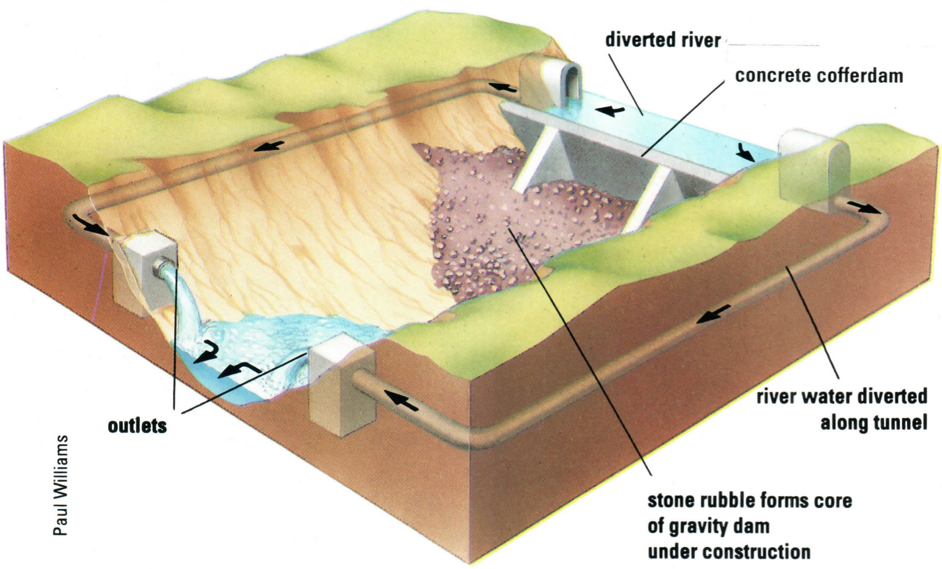
George Wimpey plc

Hydroelectric power stations are situated near the base of dams so that water from the reservoir has to fall a considerable height to reach them. The water enters a series of steep pipes and is then channelled down to the machinery in the plant. There it spins the blades of giant turbines that, in turn, are connected by shafts to a number of generators. Finally, the electricity produced by the generators enters the national grid for distribution to homes and factories.

Diversion tunnels

Before a dam can be constructed, the normal course of a river has to be temporarily diverted so that the dam site is left dry and workable. Often

Building a Dam



Paul Williams

Gamma/Frank Spooner Pictures

***Clay** was a major material used in the construction of a 3,000-metre-long embankment dam across the River Feni in Bangladesh in 1985. Bags were filled at the river's edge with clay brought down from the Chittagong Hill Tracts.*

this is done by digging underground channels in the valley's sides. Large mechanical excavators then scrape away at the old riverbed until they have exposed solid rock, on which the dam's foundations are built.

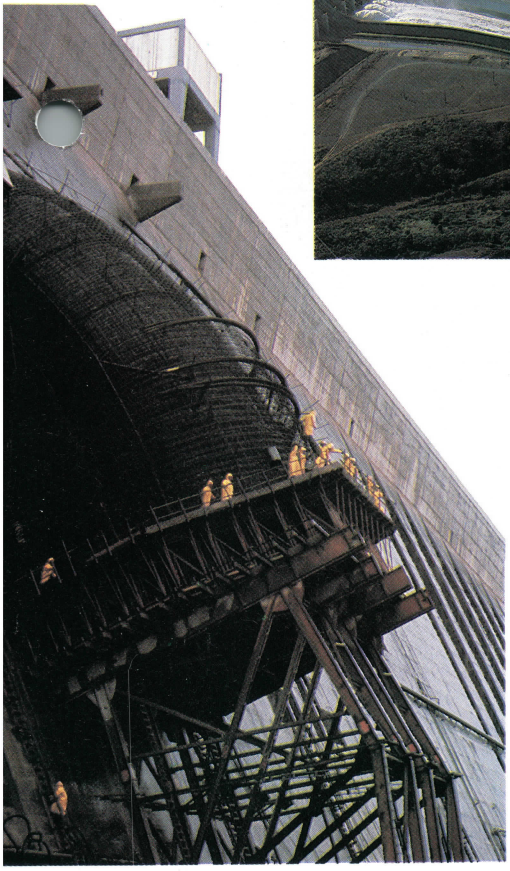
The dam itself may take one of several main forms. The Tarbela Dam, for instance, is an embankment dam, a heaped up mound of hundreds of millions of tonnes of soil and rock. When finished, such a dam is very broad at the base (where it has to withstand the greatest water pressure) and slopes up gradually on each side to a fairly narrow crest. An embankment dam like this has a core of clay, or occasionally concrete, that extends deep into the ground to prevent water from seeping underneath.

The Grand Coulee Dam is, like embankment dams, a gravity dam. It relies on its enormous weight - over 20 million tonnes - to hold back the reservoir of water behind it. But in this case, the dam wall is built from concrete. In cross-section it has the shape of a right-angled triangle with the vertical side facing the water stored in the reservoir.

***Over 28,000 workers** took more than ten years to build the Itaipu Dam. Eleven million cubic metres of concrete was used in its construction.*

Telegraph Colour Library

***The Itaipu Dam** stretches nearly 8 km across the Parana river, which runs along the Brazil-Paraguay border. When running at full power, its hydroelectric power plant will produce 12,600 megawatts from 18 turbines.*

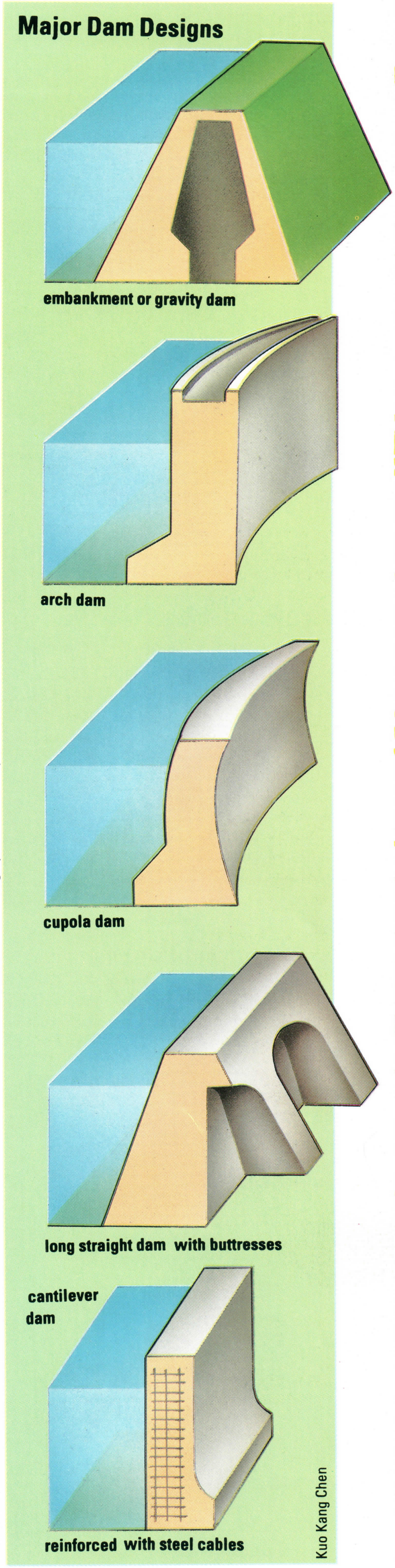


Gamma/Frank Spooner Pictures

Strong shapes

The less bulky dams, which are cheaper and faster to build, have to rely on a strong shape rather than sheer weight to resist the enormous force of water. An arch dam, for instance, curves smoothly from side to side to give it greater strength. Such a design is particularly suited to damming a narrow gorge. The curve of the arch faces upstream, and the arch transmits the pressure of water along the sides. This means that the

***Dams** are designed to hold water in huge reservoirs without crumbling. A gravity dam resists water pressure by its mass, an arch dam by distributing the load along the sides of the curve.*



Kuo Kang Chen

sides must be especially well founded on rock in the valley slopes.

A variation on this design is the cupola dam. This curves not only from side to side but also from top to bottom. An example is the 185-metre Reza Shah Kabir Dam, which spans a narrow gorge in Khuzestan, in south-west Iran.

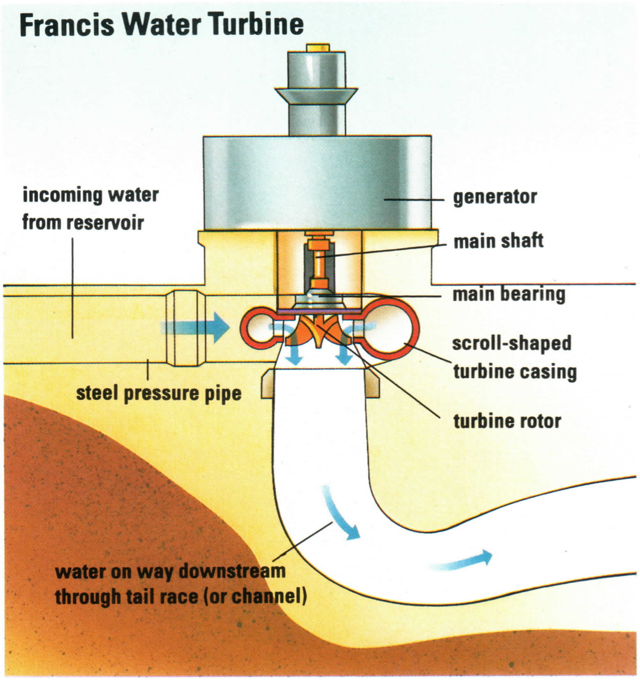
Not all dams are built to the latest engineering designs with hi-tech materials and equipment. Short of money and machinery but rich in manpower, the people of Bangladesh constructed a barrier across the mouth of the Feni River using muscle power alone.

Stopping the sea

Under the direction of a Dutch engineer, they first laid down huge reed mattresses, which were then held in place with 250,000 tonnes of rock. Next, the 15,000 workers on the project carted and placed hundreds of thousands of 45-kg bags of clay to make the dam. In one frantic 7-hour period at low tide on the 28 February 1985, 600,000 bags were put into position – by hand – to permanently seal off the river from the sea. Today, the reservoir successfully controls flooding and supplies much needed fresh water for irrigating rice crops.

More advanced tidal barriers have been set up at several sites in Europe. In Brittany, France, the estuary of the River Rance was dammed in an unusual hydroelectric scheme. The tides at the mouth of the Rance, rising 14 metres, are among the highest anywhere in the world. When the tide comes in gates in the dam open to allow the water to rush up river, but then close to trap the rising water temporarily in a reservoir. As the tide goes out, the trapped water is allowed back to the sea over a series of 24 turbines that are connected to generators.

A much larger sea dam has been built across the mouth of the Zuider Zee in the Netherlands to prevent flooding of the reclaimed lowland areas. Known as the Afsluitdijk, it stretches for over 30 km. Another highly sophisticated dam is the Thames Barrier across the River Thames, which protects london from flooding.



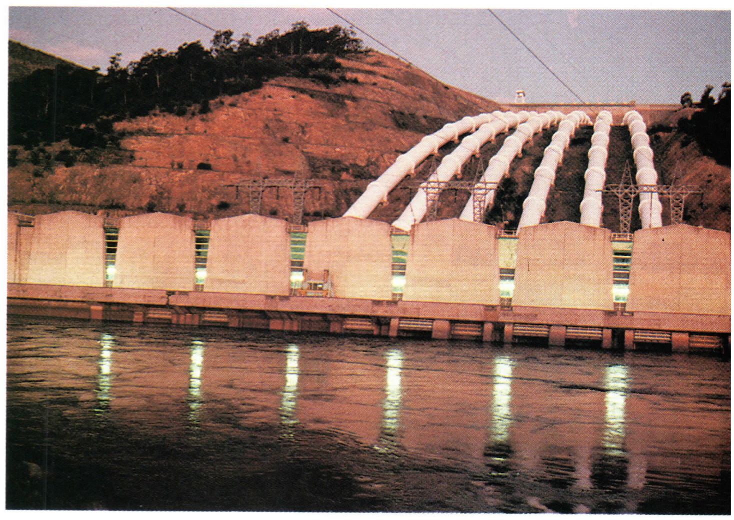
A water turbine *in a power plant converts some of the energy in a stream of water into mechanical energy that generates electricity. The mechanical power is produced by water flowing through a pipe on to a system of stationary and moving blades. The Francis turbine is the most popular type because of the wide range of 'heads' with which it can be used. (The head is the height of water above the turbines).*

Joe Lawrence

ANIMAL RESCUE

When the Itaipu Dam was built on the Brazil-Paraguay border, the cost to the environment was great. Almost 1,500 km of tropical rainforest and farmland was drowned by a giant reservoir and one of the continent's most striking waterfalls, the Sete Quedas, was lost for ever. A few weeks before flooding began in 1982, a special operation was launched to save as many wild animals as possible from drowning. Volunteers caught monkeys, lizards, porcupines, rats, spiders, turtles and many other species in the areas about to be covered with water, and then transported the animals to safety. Over 4,500 animals were rescued.

Gamma/Frank Spooner Pictures



Tumut 3 *hydroelectric power station is part of the Snowy Mountains scheme in New South Wales, one of Australia's greatest civil engineering projects. A double-decker bus has been driven up the pipes shown in the picture.*

Australian Overse Information Servi don

Just amazing!

UNDER PRESSURE

THE SAYANO-SHUSENSKAYA DAM IN THE USSR WILL BE THE STRONGEST EVER BUILT, ABLE TO WITHSTAND 18 MILLION TONNES OF WATER PRESSURE EQUIVALENT TO OVER 3 MILLION CHARGING ELEPHANTS

Paul Raymonde

ECO-ENGINES · CAR COMPUTERS · PLASTIC CARS

CAR CONSTRUCTION

Sautelet/Jerrican

CARS ARE AMONG THE MOST highly engineered items in everyday use. From the engine to the dashboard, cars are at the leading edge of technology as people demand greater performance, comfort and fuel efficiency. The three main areas of engineering research today are the engine, construction materials, and computerized electronic systems.

The heart of a car is its engine. It provides the power that is transmitted through the gearbox to keep the wheels turning. Although the internal combustion engine works on the same principles as it did in the 1870s, its design and construction now belong firmly to the 20th Century.

__Tomorrow's car__ is here today. French manufacturer Peugeot have developed the Proxima as a car of the future. It has a Kevlar/carbon-fibre body with a glass canopy that opens overhead (right). Five video screens display information, and it has a new radio guidance system.

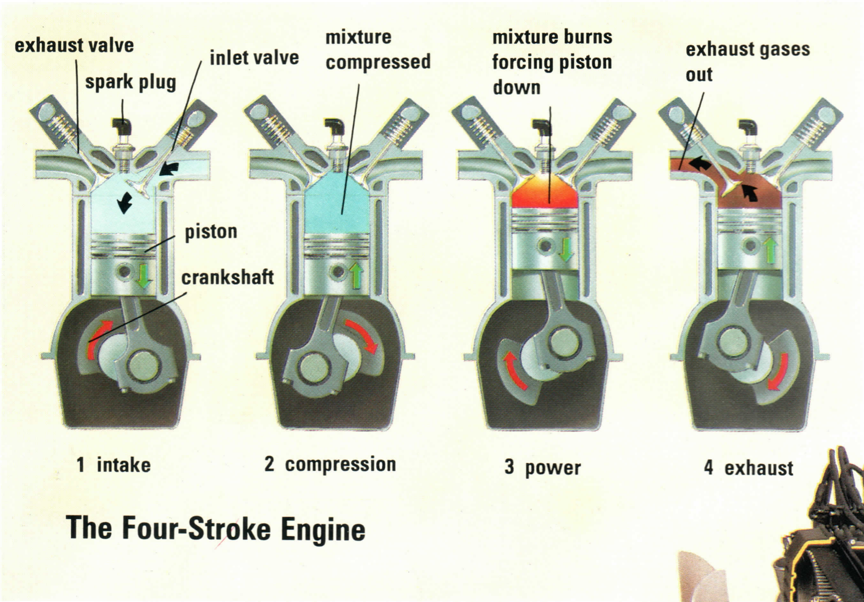
Sautelet/Jerrican

Four-stroke engines

The four-stroke petrol engine burns a mixture of fuel and air. The mixture is created in the carburettor, from where it is drawn through an inlet valve into a cylinder (induction stroke). Inside the cylinder the mixture is then compressed by the piston (compression stroke) and ignited by the spark from a spark plug. The explosion forces the piston down (power stroke), turning the crankshaft in the process. The piston then rises, forcing the waste gases out of the now open outlet valve (exhaust stroke). The outlet valve then closes and the inlet valve opens again, ready for the next intake of fuel and air.

The sequence of these events is staggered from one cylinder to the next so that the crankshaft is kept rotating smoothly. In an average family saloon at 90 km/h in top gear, the crankshaft turns about 50 times every second, or 3,000 revs per minute (rpm). The crankshaft is connected to the gearbox. This transfers the engine's power to the driving wheels, which turn at about a quarter of the speed of the crankshaft.

The gears regulate the engine's output to suit the driving requirements – lower gears supply more traction for accelerating or going uphill, and higher gears are engaged for cruising at high speed. A reverse gear is used to drive the car backwards for manoeuvring. In neutral, the gearbox allows the engine to keep running while the car is



Stan North

stationary. Most modern cars have front-wheel drive with the engine laid out across the engine bay. This means that the weight of the engine bears down on the driving wheels to give them better grip on the road.

Automatic transmission

Most cars still require the driver to depress a clutch pedal and select the gear manually, but many now have automatic transmission, where the gears change according to the engine speed. A recent development known as continuously variable transmission (CVT) allows the engine to run constantly at its most efficient speed. CVT uses a clever arrangement of expanding pulleys and a drive belt to provide any gear ratio between top and bottom gear.

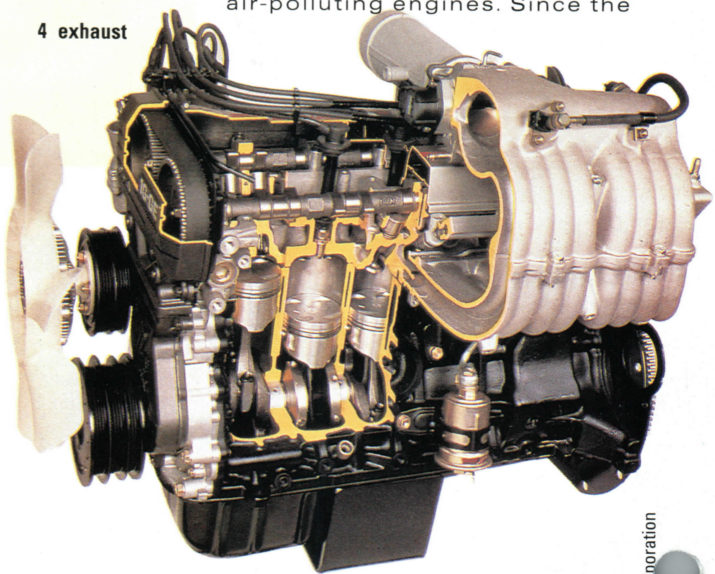
Various methods are used to boost engine performance. One way is simply to increase the number of cylinders. While most ordinary cars have 4 cylinders, more powerful models may have 6, 8, or even 12. Many now employ 16 valves, four for each cylinder, to get more fuel into the system. This gives great power and fuel efficiency. Turbocharging is another technique for getting more power out of an engine. Waste gases going down the exhaust pipe are used to drive a pump - the turbocharger - which forces the fuel and air mixture into the cylinders at great pressure. When the highly compressed mixture is ignited it can produce up to 50 per cent more power than in a normal engine. Supercharging is a similar process, but this time the fuel is forced into the cylinders by a mechanical pump instead of exhaust gases.

Lean-burn engines

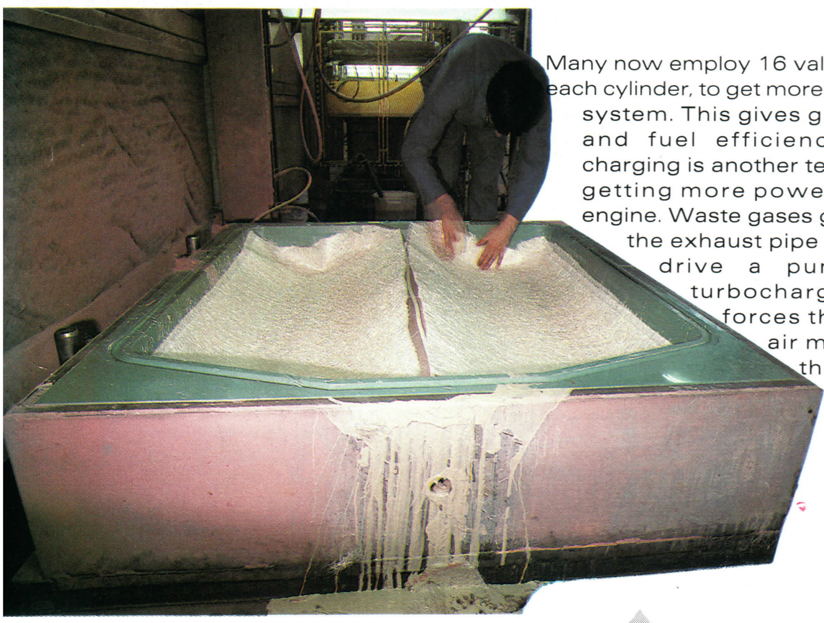
In today's highly competitive car market, engineers are always striving to increase engine performance. But in an increasingly ecology-conscious world, they have to design more fuel-efficient and less air-polluting engines. Since the 1970s, when US and Japanese governments brought in strict controls over exhaust emission, much research has concentrated on 'leanburn' technology. This still gives high performance, but reduces the amount of poisonous gases given off with car exhaust. Sensors in the carburettor linked to a cental computer make the engines highly efficient by optimizing the fuel mixture and flow.

One beneficial change has been the switch toward lead-free petrol.

***The four strokes** of an engine (right). (1) A petrol and air mixture is drawn in via the inlet valve. (2) The piston rises to compress the mixture, until a spark from the plug ignites it (3). The hot gases force the piston down, after which they are forced out (4).*

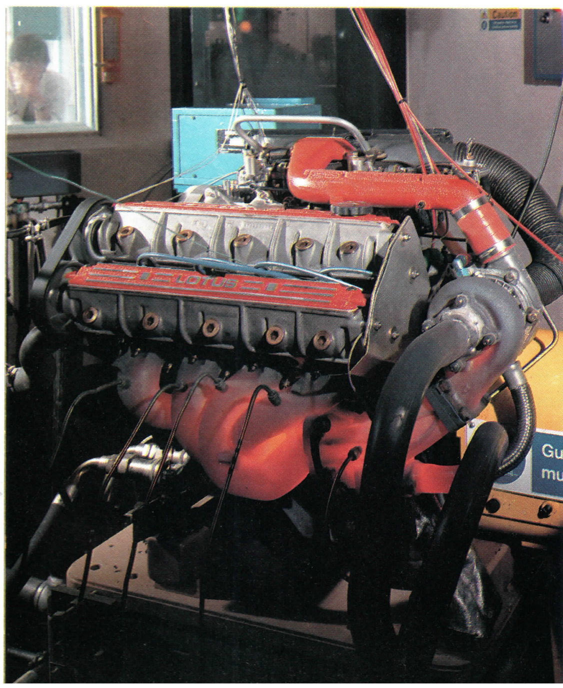


Toyota Motor Corporation



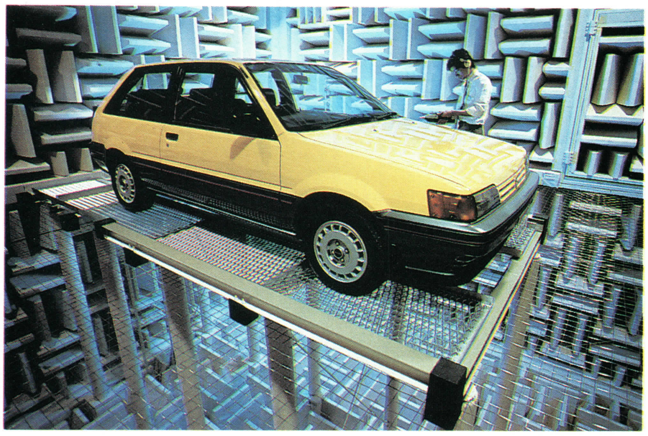
Sautelet/Jerrican

***Moulding** fibreglass body panels. Lighter materials such as plastics are being increasingly used in place of steel.*



Lotus Cars Ltd

***The exhaust** from a turbocharged engine is so hot that parts of the engine may glow bright red under hard driving conditions.*


ZEFA

An echo-free testing chamber is designed so that it will not reflect any sounds. This means that engine noises can be pinpointed exactly, and vibration problems can also be detected and ironed out.

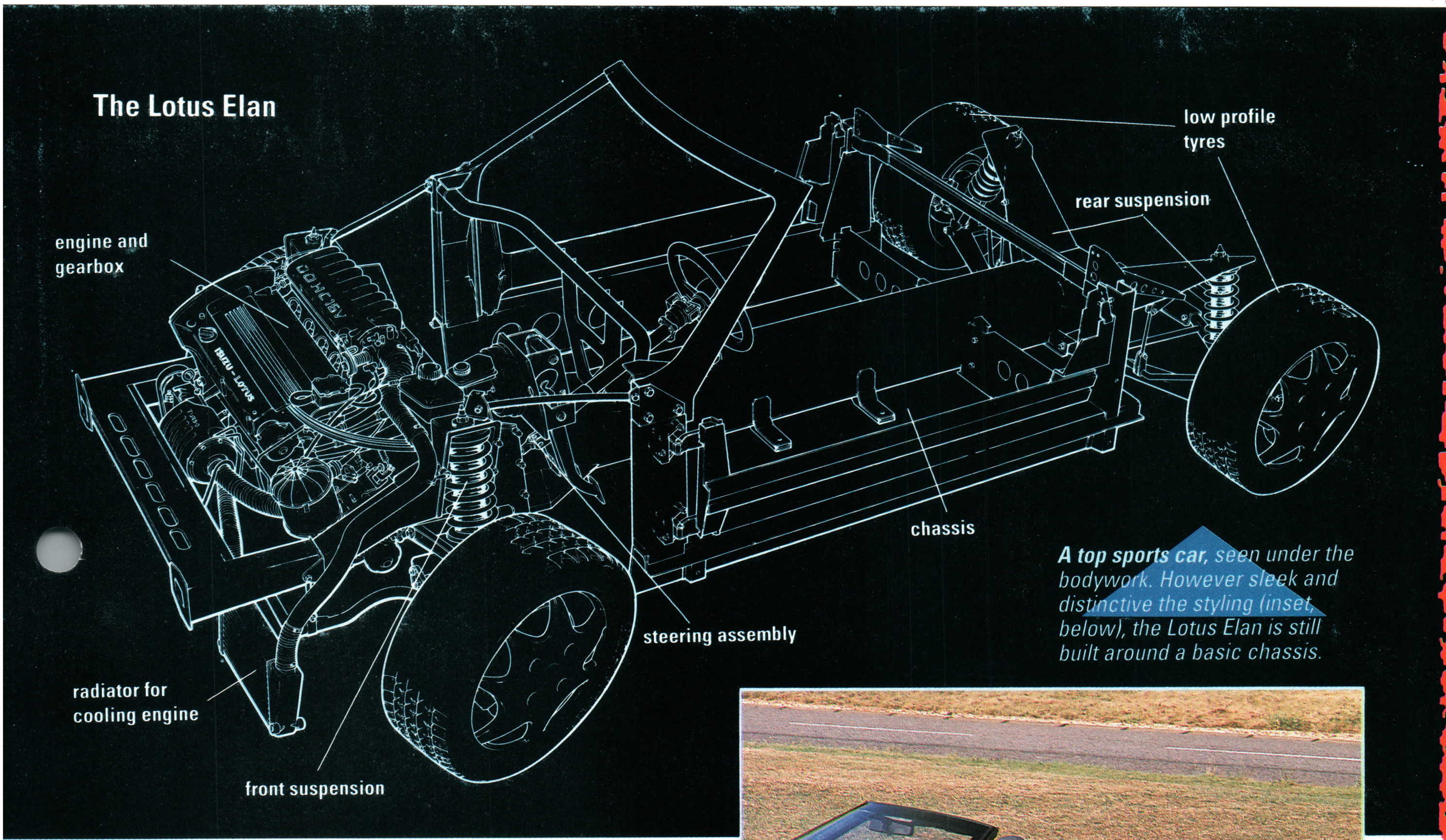
In the 1970s, the need to reduce exhaust emissions brought electronic sensors into the engine for the first time. Since then, rapid advances have led to a wide range of computers and microprocessors being used in cars. As well as monitoring and controlling engine performance, sensors are widely used, for example, in anti-lock braking systems (see NEW TECHNOLOGY, page 179).

Rear-wheel steering

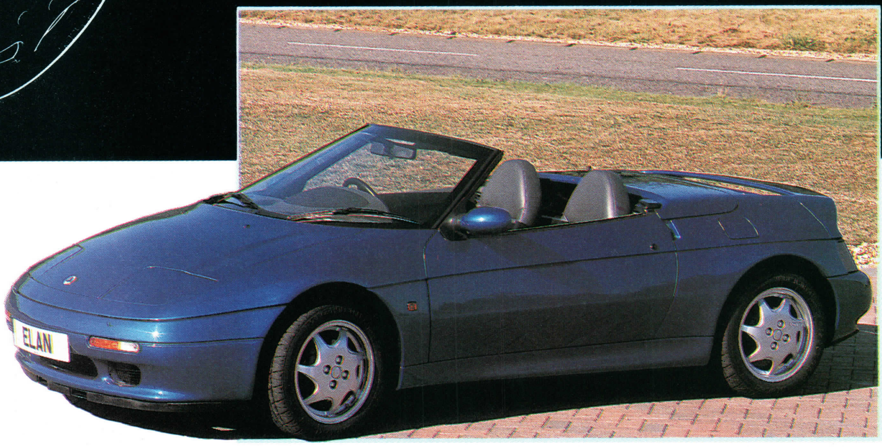
The Japanese company Toyota has produced a sports car with rear wheel steering. As the car turns a corner or hits a side wind, sensors on the rear axle detect the rate of yaw, or sideways twist, and a computer activates the rear wheels to compensate. This model also employs sensors to check tyre pressure, and has a windscreen that turns into a liquid crystal sunshade at the flick of a switch

Trip computers can display information on journey time, average speed, and fuel consumption. On some experimental cars drivers have access to electronic maps that show

Lotus Cars Ltd



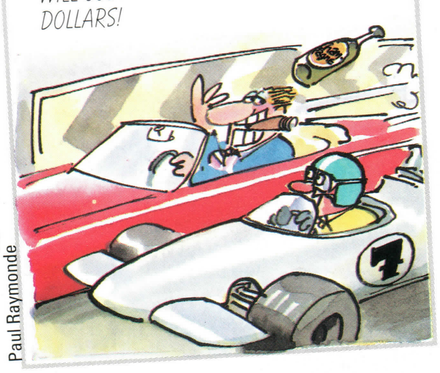
A top sports car, seen under the bodywork. However sleek and distinctive the styling (inset, below), the Lotus Elan is still built around a basic chassis.



Lotus Cars Ltd

Just amazing!

FAST MONEY
THE NEW JAGUAR XJ220 WILL BE THE WORLD'S FIRST PRODUCTION CAR CAPABLE OF OVER 320KM/H. BUT IT WILL COST AROUND HALF-A-MILLION DOLLARS!

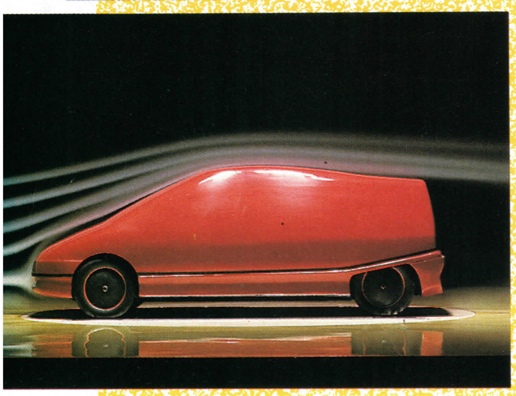

Paul Raymonde

Lead was previously added to help engine performance, but it is very poisonous. Today, lead-free petrol can be used with very little loss of performance.

Catalytic converters

The use of lead-free petrol allows cars to use devices called catalytic converters on their exhaust systems, which convert harmful gases such as carbon monoxide into harmless ones.

AERODYNAMICS – THE DRAG FACTOR

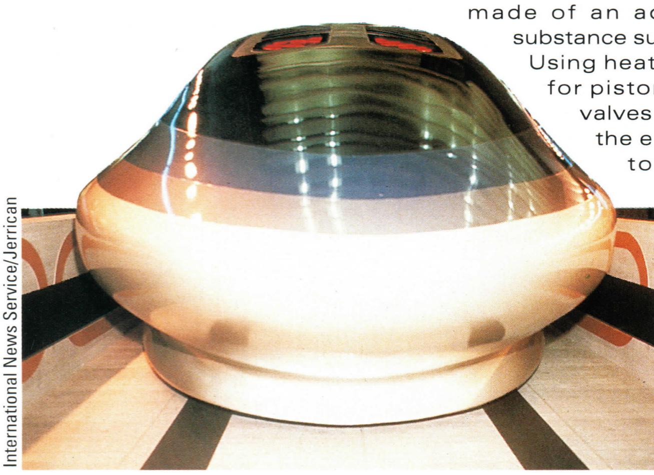


Bérenguier/Jerrican

At high speeds, up to 80 per cent of engine power may go into just forcing a car through the air. The problem is that uneven lines or sharp corners disturb the air flow, causing turbulence which drags on the car. To reduce drag, engineers simulate different car shapes on supercomputers (see FUTURES page 79), then test prototypes in wind tunnels. Illuminated smoke trails reveal how air flows around the body, while the car sits on a sensitive balance that records the amount of drag. A good aerodynamic shape is something like a teardrop.

a vehicle's current position and heading on a miniature screen. Others are fitted with satellite navigation equipment. Linked to a sophisticated radar system, an onboard computer could automatically apply the brakes or take over the steering if a collision seemed imminent.

Further into the future, cars may be able to travel at least part of the time without a driver at the controls. The required route and destination would be entered into an onboard computer that would take over as automatic pilot, using signals from a guidance system under the road.



International News Service/Jerrican

***The Linear Motor Express** is a French vehicle capable of 500 km/h. It uses a linear induction motor, which lifts up the vehicle by generating a magnetic field over the track below.*

New materials

In the past, cars were built mostly of steel, which is cheap and can be easily shaped and welded together. But in an effort to save weight and thus improve performance, a whole range of new materials are now being used for car parts.

Plastic bumpers that spring back undamaged after a low-speed impact are now common. But some plastics lack strength. To toughen them, tiny fibres of another substance can be mixed in, producing what is known as a composite. For a number of years, Chevrolet Corvettes have had their bodies moulded from plastic reinforced with 2cm-long glass-fibres.

Even stronger materials such as Kevlar, which is used in bullet-proof vests,can be combined with carbon fibre, for body shells.

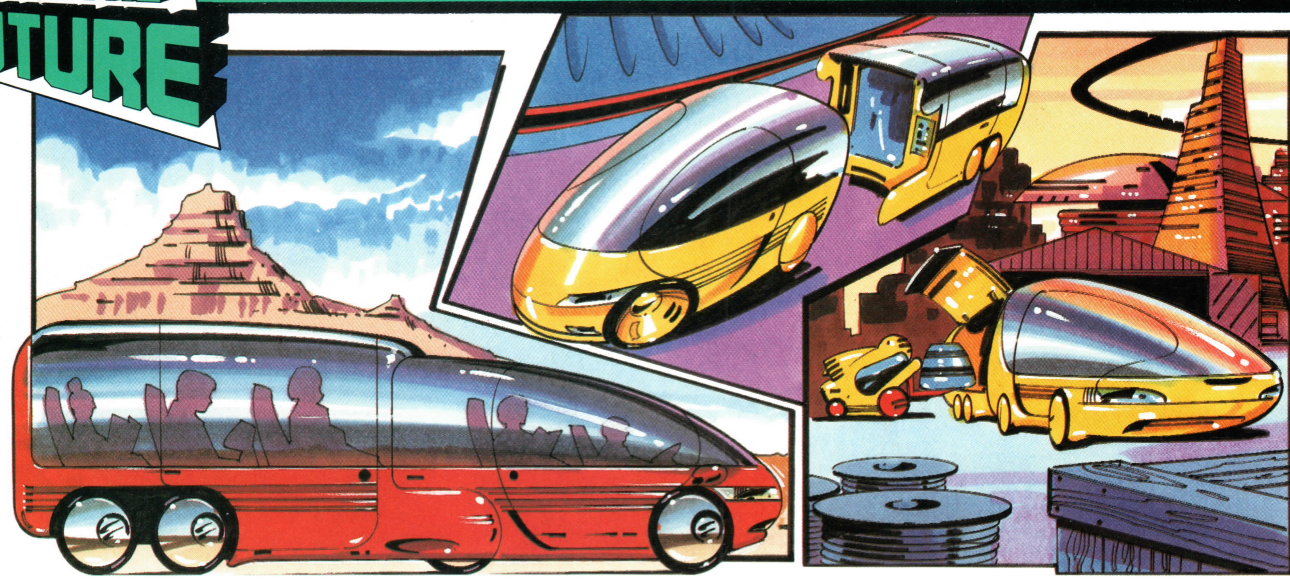
Hot Stuff

Metal engines, too, may soon become a thing of the past. Metal is not only heavy, but it cannot stand up to the high temperatures at which future engines will run. By the year 2000, some car engines may run at about 1,370° C, enabling them to use less fuel and cause less pollution. But instead of steel and aluminium, their high-temperature parts will be made of an advanced ceramic substance such as silicon nitride. Using heat- resistant ceramic for pistons, cylinder liners, valves and turbochargers, the engine will not need to be cooled by a radiator. Already ceramics are being used in the more advanced engines (see FUTURES pages 105-106).

As oil and petrol become more scarce and air pollution grows, alternative fuels are being sought, and the possibilities of hybrid electric/diesel cars explored.

INTO THE FUTURE

THE 'TWO-IN-ONE' CAR



▲ *The drivers of tomorrow will have a small car for city driving and a larger, roomy one for long journeys – simply by adapting a single vehicle.*

▲ *Both front and rear sections could be driven independently as three- and five-seaters respectively. But the two could also be combined into one large vehicle.*

▲ *The two sections will be linked electronically, with the front car acting like the command module of a spaceship. The car could be used to carry freight.*

Joe Lawrence

ARMY ENGINEERS

THE MILITARY ENGINEER IS the armed forces' unsung hero – a fighting soldier, a combat engineer and a specialist craftsman. Whenever a river or ravine must be spanned, a mine laid or enemy minefield 'swept', the engineers will be there, deploying the latest in portable, hi-tech equipment.

Paratroopers, among them engineers, swooping in at night on an enemy area where they have to mount an attack across a river, bring with them Air Portable Bridges (APBs). These are pontoons (flat-bottomed boats), light enough to be carried in an aircraft, that are bolted together to form a bridge or a ferry.

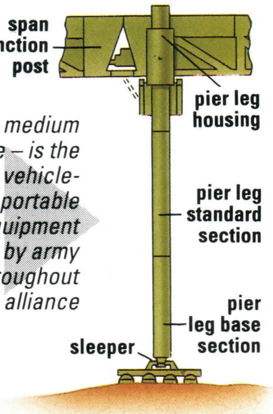
The APBs are loaded on to the aircraft on large, inflated cushion pallets with their own parachutes. The pallets are designed so that

***Royal Engineers** of the British army roll a section of a Class 30 repair mat – used to repair or rapidly make runways – on to a recovery vehicle.*

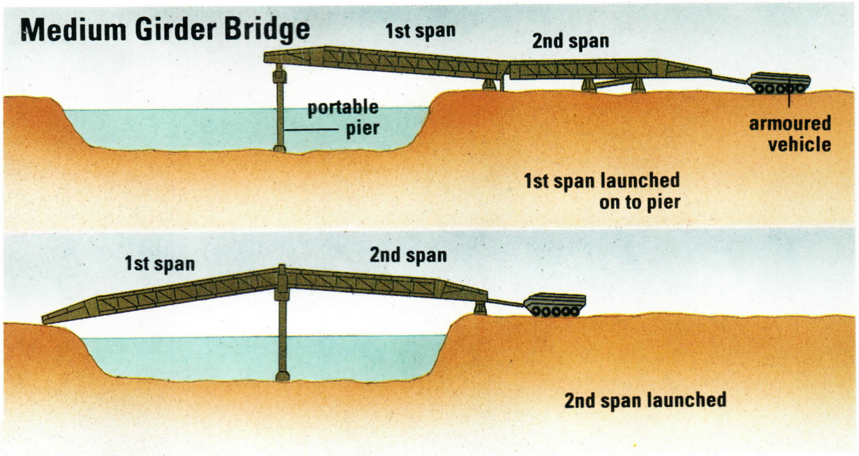
Photographic Section, Royal School of Military Engineering

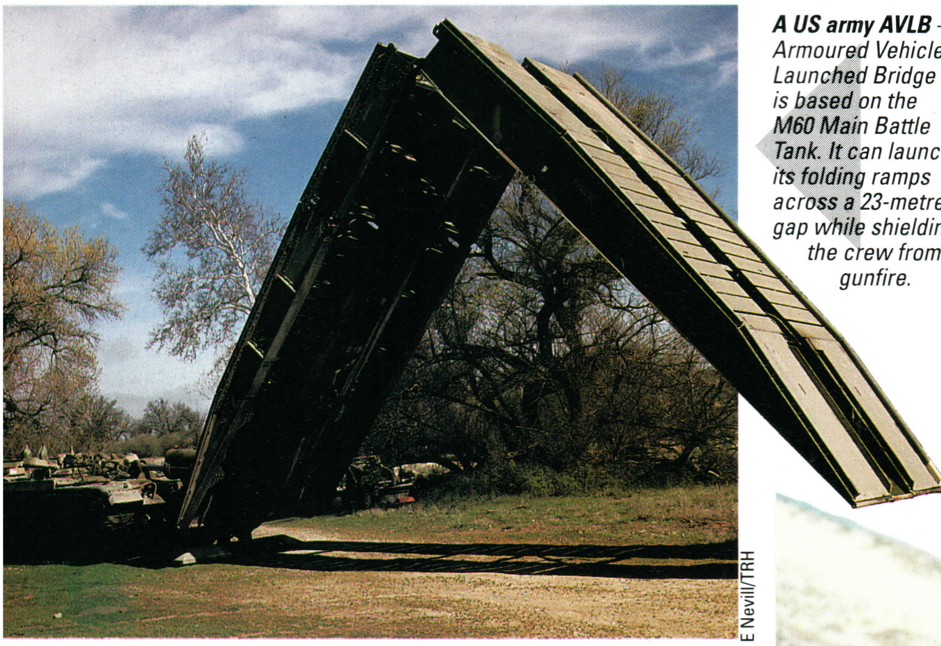
Adshead/TRH

***The M2** – a wheeled vehicle that can float and propel itself in water – is used both for bridging and ferrying heavy arrmour.*



The MGB – *medium girder bridge – is the principal, vehicle-launched, portable bridging equipment used by army engineers throughout the NATO alliance*



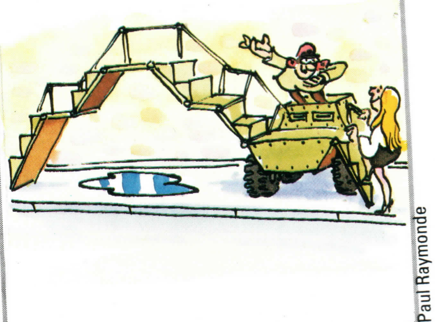


A US army AVLB – *Armoured Vehicle Launched Bridge – is based on the M60 Main Battle Tank. It can launch its folding ramps across a 23-metre gap while shielding the crew from gunfire.*

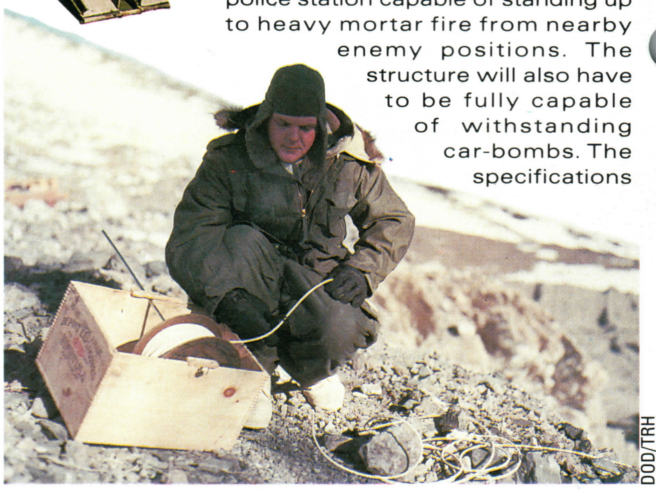
when they hit the ground the inflated sections burst, cushioning the load from the force of the drop. Each load is always marked with cy-lumes – chemically activated light markers that glow different colours in the dark – to enable the engineers to identify the various items.

Just amazing!

INSTANT BRIDGE
THE CHIEFTAIN AVLB CARRIES A SET OF FOLDING RAMPS THAT CAN EXTEND TO FORM A 23-METRE BRIDGE IN JUST FIVE MINUTES!



Engineers *are fully trained in the safe handling of explosives. Bridge demolition, for instance, is an aspect of their work, along with mine-laying, mine sweeping and the defusing of unexploded bombs.*



At first light the engineers call in heavy-lift helicopters, such as Chinooks, to ferry the APBs to a strategic point close to the intended river crossing. Under cover of night, four-wheeled-drive vehicles tow the sections down to the river.

Assembling the APB

For the purposes of this operation, the engineers assemble the APB sections in the river into a raft capable of carrying Armoured Personnel Carriers (APCs), which are like small, highly mobile tanks. They bolt the sections together fast, accurately and in silence. Then outboard engines are fitted, one at each corner.

The first wave of the attack takes place ahead of the engineers, as paratroopers cross the river in lightweight-alloy craft and engage the enemy. The engineers guide the APCs aboard, one at a time, then ferry them over to support the forward line of battle. When the last APC is across, the engineers have to dismantle the raft, sometimes under fire, so that the helicopters can haul the sections out.

Building work

In places where the army is helping to keep the peace, military engineers replace civilian engineers for building and repair jobs. For instance, they might have to build a brand new police station capable of standing up to heavy mortar fire from nearby enemy positions. The structure will also have to be fully capable of withstanding car-bombs. The specifications could include perimeter blast-walls with an outer shell of reinforced concrete slabs slotted into special steel columns. Near public roads it would have double blast walls, the gap being filled with concrete.

Heavyweight protection is needed for semi-permanent structures. When, however, engineers work in exposed positions they may sometimes have to rush up a portable Rapid Assembly Protection Wall to ward off attacks.

Temporary helipads can be rapidly assembled for emergency use in the field. They are usually sited in areas that have been scraped level, surfaced with a specialist material such as Tensar geofabric, and finally covered with crushed rock.